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August 2020
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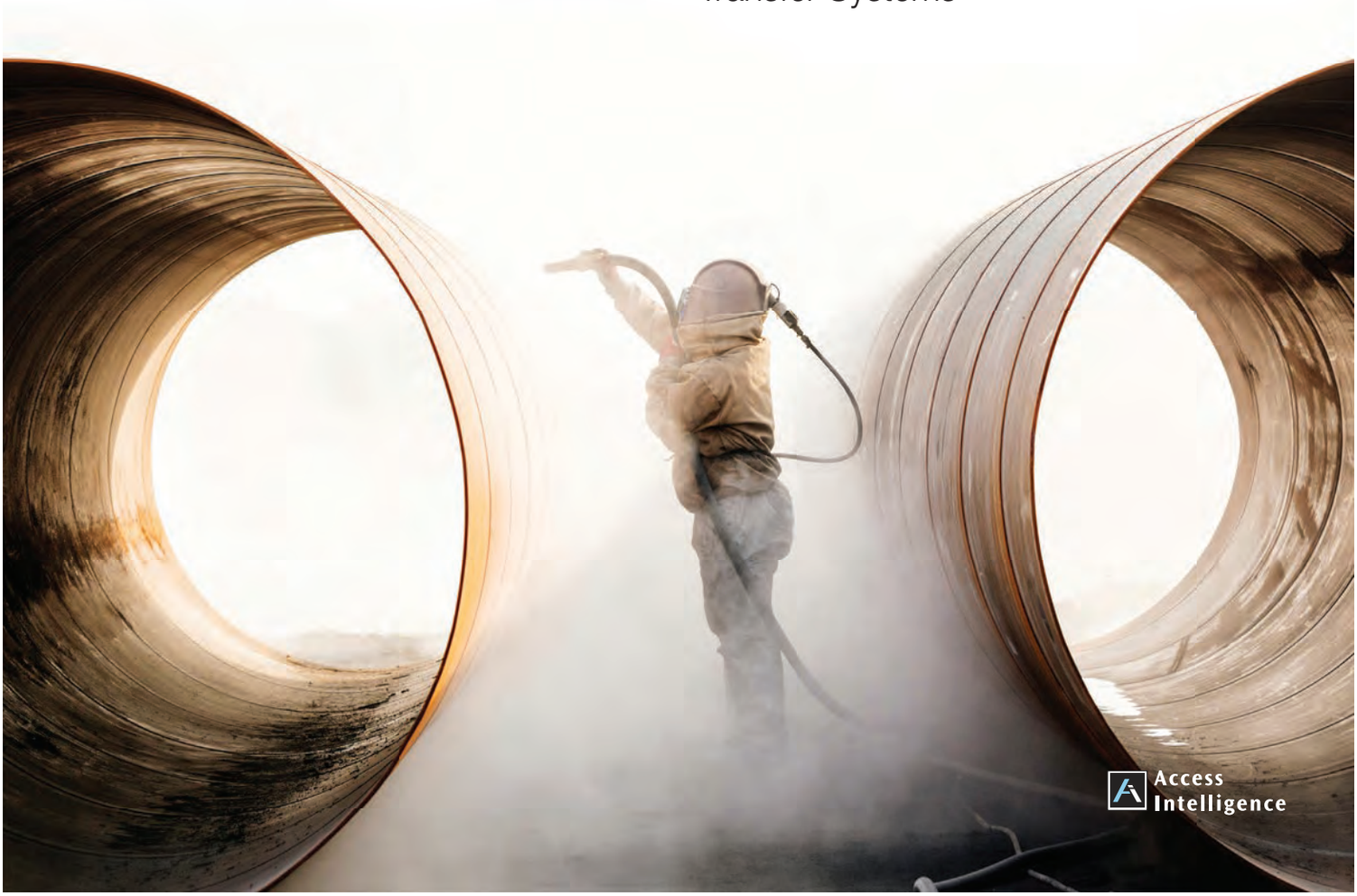

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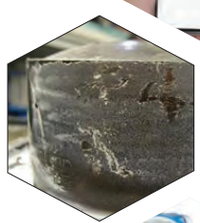

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BPA WORLDWIDE

Editor's Page

The 2020 Chopey Scholarship winner

Chemical Engineering has been a long-time leading source for practical technology information and news for the chemical process industries (CPI). In addition to providing information, we strive to help advance the chemical engineering profession. In 2007, *Chemical Engineering* established the annual Chopey Scholarship for Chemical Engineering Excellence in order to offer assistance to a student who is working toward a degree in chemical engineering. The award is named after Nicholas P. Chopey, the magazine's former Editor-in-Chief, who devoted over 47 years of his professional career to this magazine.

The 2020 winner

Virginia Jiang

Congratulations to this year's scholarship recipient, Virginia Jiang, who is a chemical engineering student at Columbia University with a planned graduation date in the spring of 2021. Jiang is conducting research in the Banta Lab for protein and metabolic engineering as it relates to designing novel, clean-energy sources, and serves as a teaching assistant for the introductory engineering course, where students learn laboratory skills and pursue short research projects in protein engineering.

A life-long curiosity in the workings of the natural world drove Jiang to pursue a career in the chemical engineering field. This year's winner has also participated in two National Science Foundation Research Experiences for Undergraduates (REUs), — one hosted at Northwestern University and one remotely by Rosetta Commons — both in protein and metabolic engineering. Jiang plans to pursue a graduate degree in chemical engineering and is excited to work in academia or industry carrying out research in the biotechnology sector.

About the scholarship

The scholarship is awarded to current third-year students who are enrolled in a full-time undergraduate course of study in chemical engineering at one of the following four-year colleges or universities, which include Chopey's alma mater and those of our editorial staff: the University at Buffalo, University of Kansas, Columbia University, University of Virginia, Rutgers University and the University of Oklahoma.

The scholarship is a one-time award. The program utilizes standard Scholarship America recipient selection procedures, including the consideration of past academic performance and future potential, leadership and participation in school and community activities, work experience, and statement of career and educational goals.

More information about the award, including how to apply and how to contribute a donation, can be found at www.chemengonline.com/npcscholarship.

In this issue

This issue contains articles on sustainable developments in coatings, corrosion-prevention technologies, mechanical pressure instruments, special considerations for pressure measurement involving hydrogen applications and a news story that takes a look at tools and technologies that are particularly suited to address COVID-19-specific safety and health concerns. There is also much more, such as the latest technology news found in our Chementator section. We hope you enjoy reading. ■

Dorothy Lozowski, Editorial Director

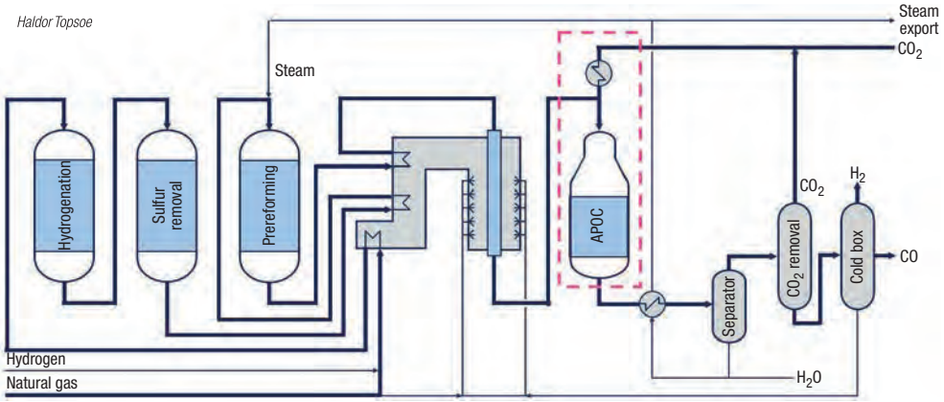
Edited by:
Gerald Ondrey

Making CO-rich syngas while avoiding carbon formation

Haldor Topsoe A/S (Lyngby, Denmark; www.topsoe.com) has developed a new technology, called ReShift, that can utilize a significant amount of CO_2 for making synthesis gas (syngas; H_2 + CO) without the traditional challenge of carbon formation. "CO_2 addition in HyCO plants typically required a high steam-to-carbon (S/C) ratio to prevent carbon formation in the reformer," says Peter Mølgaard Mortensen, principal scientist. "However, operating with a high S/C ratio is neither optimal for production of CO-rich syngas, nor energy efficient," he says.

With ReShift technology (flowsheet), the CO_2 is added downstream of the steam methane reformer (SMR), enabling the reformer to operate at lower S/C ratios. The CO_2 is heated (above 600°C) and added to the hot reformer effluent before entering an Adiabatic Post Converter (APOC). There, the mixed syngas and CO_2 are converted over a nickel-based catalyst (R-100 ReShift) into a CO-rich gas. For example, a syngas with a H_2-to-CO ratio of 2.5 leaving a SMR can be shifted to 1.0 after the APOC. Practically any H_2-to-CO ratio can be produced with this approach.

Haldor Topsoe



For new plants, ReShift technology can be included in the design, which leads to a 30% reduction in the size of the primary reformer. ReShift can also be used to boost CO production capacity in existing plants, while lowering the carbon footprint of the plant. ReShift technology can be applied downstream an SMR or an autothermal reformer (ATR).

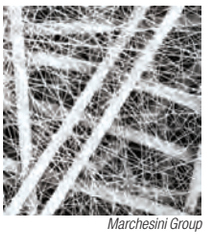
The process is based on known process and catalyst systems and the catalyst has been tested in laboratory at ReShift conditions. The elements of the APOC reactor are similar to Haldor Topsoe's proven ATR reactor systems. The technology has been released for sale for first commercial unit.

Italian industry-academic collaboration yields prototype machine for making new masks

The Marchesini Group S.p.A. (Pianoro Bologna, Italy; www.marchesini.com) and a multidisciplinary research group at Bologna University (www.unibo.it) have created a prototype that manufactures "super" filtering material for face masks with greater protection against viruses and bacteria compared to materials currently in use. Moreover, the filter media (photo) has an excellent particle-filtration capacity, and can be applied to fabrics not normally used to produce face masks.

"The prototype enables industrial-scale production of this new type of filtration material, based on electrocharged polymer nanofibers," explains Andrea Zucchelli, a professor with the Dept. of Industrial Engineering (DIN) at Bologna University, and one of the project coordinators. Once up and running, the prototype, which is housed in the laboratory of the DIN in Bologna, will produce enough filtration material for around seven thousand masks per day. The first production runs of these materials will be used to produce a prototype batch of FFP3-type masks by GVS S.p.A. (Zola Predosa, Italy).

The group was led by professors Zucchelli, Maria Letizia Focarete of the Giacomo Ciamician Dept. of Chemistry and Davide Fabiani of the Guglielmo Marconi Dept. of Electrical, Electronic and Information Engineering. "Only a University environment could nurture and support a project of this kind, designed to rapidly and effectively combine notions from the fields of mechanical engineering, polymer research and electrical engineering to develop an advanced electrospinning technology," Zucchelli says. "Thanks to this synergy, we succeeded in combining electrospinning technology, which allows us to produce material with nanometric fibers, with corona discharge, thanks to which we were able to obtain nanofibers with a high electrostatic charge".



Marchesini Group

"Together with connectors for face masks, which we produced using 3D-printing technologies, this prototype further demonstrates how technology can also be used to meet society's needs, both during this pandemic and afterwards," says Maurizio Marchesini, chairman of Marchesini Group.

CURING WITH LESS Pt

Silicone-release coatings generally use a platinum-based curing catalyst. Aiming to reduce the amount of this expensive precious metal, Shin-Etsu Chemical Co. (Tokyo, Japan; www.shinetsusiliconesglobal.com) has developed a Reduced-Platinum Reaction-Curing System Technology that lowers Pt usage by about half, compared to that of conventional usages. This is achieved by implementing a silicone composition that exhibits high reactivity. Shin-Etsu Chemical and its U.S. subsidiary, Shin-Etsu Silicones of America, Inc. (SESA; Akron, Ohio), are proceeding with commercialization by integrating this technology into silicone release coatings.

Notably, silicone release coatings add peelability (releasability) to adhesive agents by coating such backing materials as paper and film. These applications include coated release

(Continues on p. 6)

paper for stickers, labels and adhesive tapes. Additionally, they work for release films and manufacturing process release liners and a myriad of other applications.

MAKING SPIDER SILK

Spiders produce strong and lightweight threads called draglines that are made from silk proteins. Although such silks can be used to manufacture a number of useful materials, getting enough of the protein is difficult because only a small amount can be produced by each spider. In a new study published in *Communications Biology*, a research team, led by Keiji Numata at the Riken Center for Sustainable Resource Science (CSRS; Yokohama, Japan www.riken.jp), reported that they succeeded in producing the spider silk using photosynthetic bacteria. This study could open a new era in which photosynthetic bio-factories stably output the bulk of spider silk.

The CSRS researchers focused on the marine photosynthetic bacterium *Rhodovulum sulfidophilum*. This bacterium is ideal for establishing a sustainable bio-factory because it grows in seawater, requires CO_2 and N_2 from the atmosphere, and uses solar energy, all of which are inexhaustible.

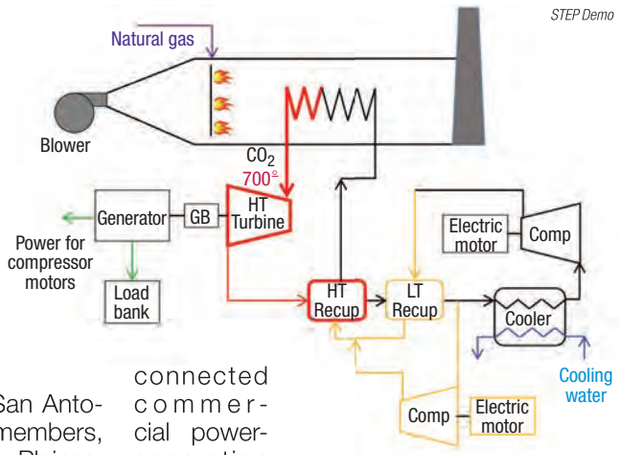
The bacterium was genetically engineered to produce MaSp1 protein, the main component of the *Nephila* spider dragline, which is thought to play an important role in the strength of the spider silk. Optimization of the gene sequence that they inserted into the bacterium's genome was able to maximize the amount of silk that could be produced. They also found that a simple recipe — artificial seawater, bicarbonate salt, N_2 gas, yeast extract, and irradiation with near-infrared light — allows *R. sulfidophilum* to grow well and produce the silk protein efficiently. The surface and internal structures of the fibers produced in the bacteria were found to be very similar to those produced naturally by spiders.

F-T SYNTHESIS

Even though more than one hundred years have passed

(Continues on p. 8)

A step toward supercritical-CO_2 power generation



Construction is complete on a new building to house a fully integrated electricity-generating power plant that will demonstrate operability and performance of a 10-MW power-generation facility using supercritical carbon dioxide (sCO_2) as the working fluid in a Brayton thermodynamic cycle. Known as the STEP (supercritical transformational electric power) Demo project, the pilot-plant test facility is located on the property of Southwest Research Institute (San Antonio, Tex.), one of the STEP team members, along with project-leader GTI (Des Plaines, Ill.; www.gti.energy), GE Research (Niskayuna, N.Y.), and the National Energy Technology Laboratory (Morgantown, W.Va.).

The sCO_2 cycle (diagram) offers significant potential benefits in efficiency, cost and environmental performance over the steam Rankine cycle, a common method for producing electricity currently. Above its critical point, CO_2 has properties of both a gas and liquid. "In a Rankine cycle, you have a liquid-vapor phase change," explains John Marion, GTI senior program director. "In a Brayton cycle with sCO_2, there is no phase change — sCO_2 behaves like a gas, but it's non-compressible like a liquid — and that allows overall cycle efficiencies of over 50% (2 to 5 percentage points higher than steam Rankine), and allows the turbomachinery components to be 10 to 30 times smaller than those for Rankine cycles." These attributes result in a levelized cost of energy that is 3–4% lower than with steam cycles.

The objective of the STEP Demo is to integrate all the elements required for a grid-connected commercial power-generation plant, which has not been done previously, although sCO_2 Brayton cycles have been used in smaller, niche applications. Major equipment components have been fabricated and delivered for assembly.

Recent advances in materials and turbine modeling have allowed the Brayton sCO_2 cycle in a practical system for power generation, says Don Stevenson, GTI vice president of energy supply. In order to realize the efficiency gains with the sCO_2 Brayton cycle, the system needs to operate at high (500–700°C) temperatures, which necessitates materials that can withstand the temperatures, for example.

Other technological advances developed and built for the STEP Demo project include high-temperature, printed-circuit heat recuperators, a monolithic turbine rotor and the application of dry gas seals for the turbine and compressor, Marion says.

The STEP project leaders anticipate commissioning and testing the pilot facility in summer 2021. It is funded by the U.S. Department of Energy and by industry partners.

Stainless-steel alloy for additive manufacturing

QuesTek Innovations LLC (Evanston, Ill.; www.questek.com) has introduced a stainless-steel powder designed for additive manufacturing (AM; 3D printing) that allows complex, high-strength parts to be made without the need for expensive post-treatments, such as cryogenic processing or high-temperature heat treatment. Designed for powder-bed fusion 3D printing, the new powder overcomes the poor and variable properties observed when using 17-4 steel (17% Cr; 4% Ni) in 3D printers.

Dana Frankel, QuesTek Manager of Design and Product Development says "With QuesTek's QT 17-4 powders, a fully martensitic microstructure is achieved in the as-printed condition. The high-temperature solution heat-treatment process, required for conventional 17-4, is not needed for QuesTek's alloys, and the resulting properties have less variation." The corrosion resistance and fatigue performance of AM alloys made from these powders is equivalent or improved over AM material printed using commercially available 17-4 powders, QuesTek says.

The company's new powders can be used in a wide range of industries, including aerospace, defense, medical, chemical processing and energy. QuesTek is in discussions with commercialization partners, including alloy producers, metal AM machine manufacturers and service bureaus to license these technologies and accelerate commercial adoption.

since the discovery of Fischer-Tropsch (F-T) technology, the processes involved are still not fully understood scientifically. "This applies in particular to the structural changes in the catalysts required for the process under industrial conditions," says professor Jan-Dierk Grunwaldt from the Institute for Chemical Technology and Polymer Chemistry (ITCP) at the Karlsruhe Institute of Technology (KIT; Germany; www.kit.edu). "During the reaction, undesirable byproducts can be formed or disruptive structural changes in the catalyst can occur," explains Grunwaldt. "So far, it has not been explained sufficiently how this happens exactly during the reaction and what the effects on the overall process are."

In a transdisciplinary project, in cooperation with colleagues from KIT's Institute for Micro Process Engineering (IMVT) and the Institute of Catalysis Research and Technology (IKFT), the team has now achieved a breakthrough in understanding F-T synthesis at the atomic level. "For the analysis, we use methods of synchrotron research, namely X-ray absorption spectroscopy and X-ray diffraction," explains Marc-André Serrer (IKFT), one of the authors of the study published in *Reaction &*

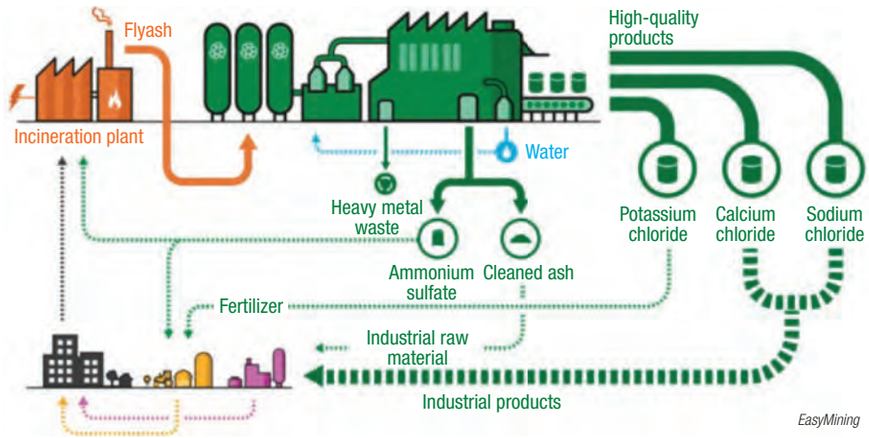
(Continues on p. 9)

Commercial plant will recover salts from incinerator flyash

Ragn-Sells AB (Sollentuna, Sweden; www.ragnsells.com) has partnered Hitachi Zosen Inova AG (Zürich, Switzerland; www.hz-inova.com) for the construction of a new plant that is designed to extract resources from flyash — a toxic byproduct of waste incinerators that normally ends up in landfills. When the facility starts up by 2022, it will be able to process flyash corresponding to half of the yearly production in Sweden.

The plant is based on the Ash2Salt technology, a patented process developed by Ragn-Sells' subsidiary EasyMining AB (Uppsala, Sweden; www.easymining.se). In the process, flyash is first washed, creating a leachate solution containing chloride salts and heavy metals. The leachate is filtered, and the detoxified residue — with much smaller volume than the original ash — safely landfilled, or used in construction materials. The heavy metals are removed from the leachate by precipitation with sulfide, and ammonia recovered as ammonium sulfate, leaving a solution of chloride salts. The salts are then separated using a single evaporator by a patented process, to produce commercial-grade KCl, NaCl and $CaCl_2$. One ton of flyash can contain as much as 400 kg of salts.

Each year, Sweden produces roughly 300,000 metric tons of fly ash. Around half is sent to a discontinued limestone quarry on the Norwegian island of Langøya (near Oslo). This practice means that neither resources nor toxic substances are extracted. Additionally, the Langøya quarry will reach maximum capacity and close down within a few years.



The plant, which is now under construction at Ragn-Sells' Högbytorp site in Bro (outside Stockholm), is one of the largest single investments ever within the Swedish material-recycling sector.

New method makes nanocellulose composites industrially viable

Cellulose nanoparticles are of great interest as constituents of polymer composite materials because they can dramatically increase strength and toughness in a range of different polymer types. "Cellulose nanoparticles can be thought of as a more sustainable version of carbon nanotubes, in the way they can improve mechanical strength performance for composites," explains Jeffrey Youngblood, a materials engineer at Purdue University (West Lafayette, Ind.; www.purdue.edu) who leads a laboratory exploring them.

However, the economic production of polymer composites using cellulose nanomaterials has been stymied by difficulties in dispersing the materials effectively throughout the polymer resins. Solvents can be used to disperse the materials, but that approach requires composite manufacturers to install additional processing steps for the solvents and emissions control devices, which raise the cost of the composites. Now, researchers in Youngblood's laboratory have developed a method to disperse nanocellulose into polymers without the need for solvents.

"Cellulose is a very hydrophilic material, so it is difficult to introduce it into hydrophobic polymers," Youngblood explains, adding that effective dispersal is critical because at the nanoscale, the cellulose particles tend to aggregate, which negates the potential performance benefits in the composite material.

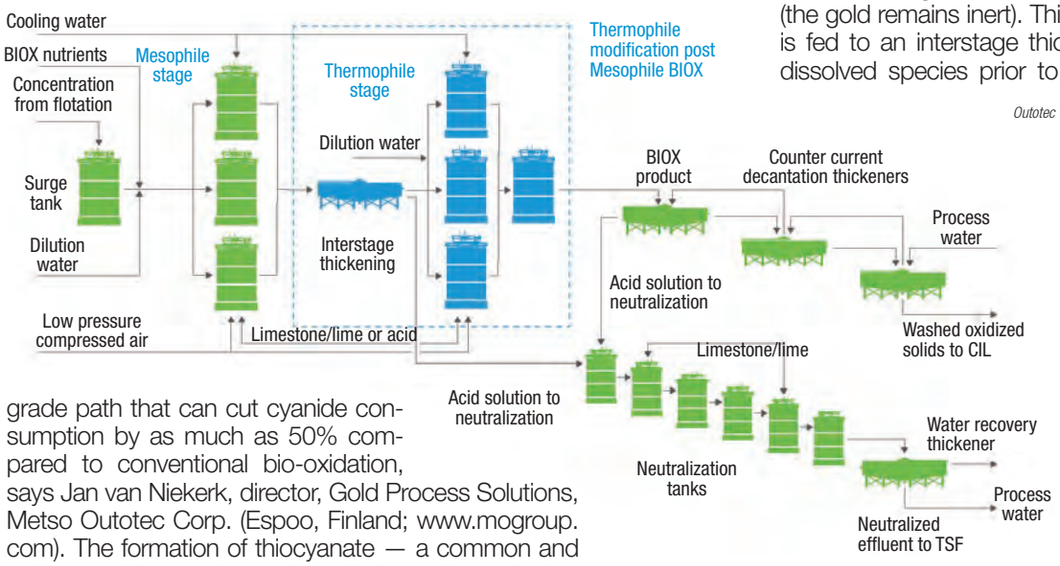
The Purdue team has taken the approach of using common polymer additives as carriers that introduce the nanocellulose into the polymer in an dispersed way. Common additives for polymer resins, such as plasticizers or colorants, can be used to introduce the nanocellulose into the polymer without the use of solvents, he says.

Using this compounding approach, the research team introduced cellulose nanoparticles into the biopolymer polylactic acid (PLA), which has shown improved strength performance, as well as nylon-6 fibers, ethylene vinyl alcohol (EVOH; used in packaging films), polymethylmethacrylate (PMMA) and others. The nanocellulose content varies by polymer type, but can have an upper limit between 5 and 20%, depending on the polymer. Nanocellulose particles can also be used at low levels to nucleate crystalline regions in a polymer.

The team is testing the strength properties of the polymer composites and looking for licensing partners.

Significantly reduce cyanide consumption in refractory gold-ore treatment

Traditionally, cyanide consumption with conventional bio-oxidation residues is higher than with residues produced through other oxidative technologies. The Outotec MesoTherm BIOX process, based on its proven mesophile BIOX process, offers an easy, cost-effective upgrade path that can cut cyanide consumption by as much as 50% compared to conventional bio-oxidation, says Jan van Niekerk, director, Gold Process Solutions, Metso Outotec Corp. (Espoo, Finland; www.mogroup.com). The formation of thiocyanate — a common and stable cyanide species traditionally formed as a further byproduct — is also reduced by more than 50%, he says.



Outotec

The MesoTherm BIOX process enhances the established mesophile BIOX process by combining mesophile bio-oxidation technology with a thermophile oxidation stage. The thermophile stage operates at a higher temperature (about 65°C) than the mesophile stage (40–42°C), thereby achieving an even more-effective overall sulfide-oxidation step, says Van Niekerk.

In the complete process (flowsheet), fresh concentrate slurry — which contains gold, sulfide minerals (such as pyrite and arsenopyrite) and gangue minerals (such as silicates or dolomite) — process water and some nutrients are fed to the mesophile stage. There, bacteria oxidize some of the sulfide minerals, releasing iron, arsenic and sulfate into solution (the gold remains inert). This partially oxidized slurry is fed to an interstage thickener to remove some dissolved species prior to the thermophile stage. The partially oxidized solids are pumped to the thermophile reactors, where the sulfide is further oxidized to achieve near 100% oxidation, explains Van Niekerk. The BIOX product then undergoes a three-stage, counter-current decantation (CCD). The washed oxidized solids from the final CCD thickener are then pumped to the leaching section (carbon in leach; CIL), where cyanide is added to dissolve the liberated gold.

The new process is currently being implemented at the Fairview BIOX plant in South Africa, where the mine has converted one of its secondary mesophile reactors into a thermophile reactor. This reactor was operated as a production reactor, as part of the process. The plan is to convert more of the secondary reactors to thermophile reactors over time, says Van Niekerk.

Turning plastic waste into high-quality winter diesel fuel

Using a proprietary technique and Clariant's (Muttenz, Switzerland; www.clariant.com) Hydex E next-generation hydro-dewaxing catalyst, VUCHT a.s (Bratislava, Slovakia; www.vucht.sk) has successfully converted plastic waste into premium winter-fuel distillate. The efficacy of this process has now been proven in a pilot plant in Slovakia.

VUCHT is the research institute of part of Duslo a.s. (Šal'a, Slovakia), a major Slovak producer of fertilizers, specialty nitrogen compounds and rubber chemicals. The institute uses a pyrolysis process to convert a variety of plastic waste collected in the country, such as polyethylene (PE), polystyrene (PS), polypropylene (PP) and polyethylene terephthalate (PET), into diesel fuel. The process thermally degrades the plastic at temperatures above 300°C (530°F), converting it into liquid oil comprised of various hydrocarbon compounds. Recently, the institute developed a proprietary technique to further convert the liquid oil into a high-quality fuel distillate known as winter diesel.

The winter diesel produced is compliant with Euro 6 fuel-emission standards, including cold-flow properties specified for temperatures as low as –30°F (–34°C), typically required in arctic areas. To achieve this extreme improvement in cold flow, Clariant's Hydex E hydro-dewaxing catalyst was applied. Hydex E is a selective zeolite-based isomerization hydro-dewaxing catalyst developed for highly paraffinic feedstocks.

After intensive pilot testing proved the technical viability and economic appeal of the process, VUCHT is planning to expand the method's success in a custom-built demonstration plant, which will have a fuel-distillate capacity of 40 metric tons per year (m.t./yr). ■

Chemical Engineering. "This was the first time that we were able to watch, so to speak, an F-T synthesis catalyst at work at the atomic level under real process conditions."

For the experiment at KIT, a high-pressure infrastructure has now been added to the CATalysis and ACTinide measuring line (CAT-ACT) at the KIT synchrotron. With this infrastructure — which was built as part of Germany's Kopernikus projects for the energy transition — it was possible to determine the function of a commercial cobalt-nickel catalyst operating at 250°C and 30 bars for more than 300 hours during the F-T synthesis. This was also the first time that a sufficient quantity of hydrocarbons could be produced in such an experiment that could be analyzed afterwards. ❐

LINEUP

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Plant Watch

Nouryon to build TBHP/TBA plant in Ningbo

July 8, 2020 — Nouryon (Amsterdam, the Netherlands; www.nouryon.com) will start development of a new manufacturing facility at its site in Ningbo, China to produce two key intermediates for its organic peroxides business — *tert*-butyl hydroperoxide (TBHP) and *tert*-butyl alcohol (TBA). The manufacturing facility is scheduled to be completed in the second half of 2021, and will have capacity to produce 35,000 metric tons per year (m.t./yr) of TBHP/TBA.

Major hydrogen and ammonia project underway in Saudi Arabia

July 7, 2020 — Air Products (Lehigh Valley, Pa; www.airproducts.com) signed an agreement with ACWA Power and NEOM for a $5-billion ammonia plant powered by green hydrogen. Located in northwest Saudi Arabia, the new plant will produce 650 m.t./d of hydrogen via electrolysis and 1.2 million m.t./yr of green ammonia. The project is scheduled to be onstream in 2025.

Linde starts up plants to supply Celanese and other U.S. Gulf Coast customers

July 7, 2020 — Linde plc (Guildford, U.K.; www.linde.com) started up a new hydrogen and carbon monoxide facility in Clear Lake, Tex., as well as a new air separation unit in LaPorte, Tex. The plants will supply oxygen, nitrogen and carbon monoxide to Celanese Corp. (Dallas, Tex.; www.celanese.com) and hydrogen to other customers via Linde's U.S. Gulf Coast pipeline system.

Equinor to build world-scale clean hydrogen plant in the U.K.

July 1, 2020 — Equinor ASA (Stavanger, Norway; www.equinor.com) is leading a project to develop one of the world's first at-scale facilities to produce hydrogen from natural gas in combination with carbon capture and storage. The project will be located at Saltend Chemicals Park near Hull, U.K., and its initial phase comprises a 600-MW autothermal reformer with carbon capture, the largest plant of its kind in the world. Equinor and its partners expect the project to start up by 2026.

Air Products starts up Geismar steam-methane reformer to supply Huntsman

July 1, 2020 — Air Products started up its new steam-methane reformer and cold box in Geismar, La. to supply neighboring facilities owned by Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com). The facility produces around 6.5 million ft^3/d of CO, 50 million ft^3/d of hydrogen, and up to 50,000 lb/h of steam, with the capability to further increase CO supply.

Teijin to expand carbon-fiber production in Germany

June 29, 2020 — Teijin Group's (Toyko; www.teijin.com) carbon-fiber business in Germany has increased production capacity for its chopped carbon-fiber product, Tenax-E HT C604 6mm, by 40%. The expansion responds to growing carbon-fiber demand in Europe for electronics and medical devices.

Calgon Carbon to expand activated-carbon production plant in Mississippi

June 29, 2020 — Calgon Carbon Corp. (Pittsburgh, Pa.; www.calgoncarbon.com) intends to expand capacity at its Pearlington, Mississippi plant by investing $185 million to build a second production line for virgin granulated activated carbon. When completed, Calgon Carbon's virgin granular activated-carbon capacity will exceed 90,000 m.t./yr.

Braskem completes construction of La Porte polypropylene plant

June 24, 2020 — Braskem America (Philadelphia, Pa.; www.braskem.com/usa) completed construction of its new polypropylene (PP) plant located in La Porte, Tex. The new plant has a production capacity of over 450,000 m.t./yr of PP, and has the capability to produce homopolymer, impact copolymer and random copolymers.

Grace doubles colloidal silica capacity with new plant in Germany

June 23, 2020 — W. R. Grace & Co. (Columbia, Md.; www.grace.com) opened a new colloidal silica plant at its European flagship manufacturing center in Worms, Germany. The facility doubles Grace's worldwide production capacity for Ludox, a colloidal silica product.

Solvay starts up hydrogen peroxide facility in Vietnam

June 22, 2020 —Solvay Peroxides Vietnam, a global business unit of Solvay S.A. (Brussels, Belgium; www.solvay.com), started production at its new hydrogen peroxide plant in Long An Province, Vietnam. This facility is designed with a production capacity of 24,000 m.t./yr to meet growing local demand for hydrogen peroxide for the textile industry and other applications.

Tosoh to expand bromine production capacity

June 22, 2020 — Tosoh Corp. (Tokyo; www.tosoh.com) plans to expand production capacity for bromine at its Nanyo Complex in Shunan City, Japan. With an investment of around ¥10 billion (around $93 million), this expansion will result in an approximately 30% increase over present capacity. The expansion is expected to be complete in January 2023.

Mergers & Acquisitions

Petrobras to sell biodiesel assets

July 7, 2020 — Petróleo Brasileiro S.A. (Petrobras; Rio de Janeiro, Brazil; www.petrobras.com.br) has started the process to sell its wholly owned subsidiary Petrobras Biocombustível S.A. (PBIO). This transaction consists of the sale of 100% of Petrobras' shares in PBIO, including three biodiesel plants.

Dow to divest U.S. rail infrastructure assets

July 6, 2020 — Dow, Inc. (Midland, Mich.; www.dow.com) agreed to sell its rail infrastructure assets and related equipment at six North American sites to Watco Companies, LLC (Pittsburg, Kan.; www.watcocompanies.com). Dow expects to receive proceeds of around $310 million as part of the transaction. The assets are located at Dow's sites in Plaquemine and St. Charles, La.; Freeport and Seadrift, Tex.; and Ft. Saskatchewan and Prentiss in Alberta, Canada.

Lummus Technology acquisition completed

July 1, 2020 — Haldia Petrochemicals Ltd. (Kolkata, India) and investment funds affiliated with Rhône Capital have successfully completed the joint acquisition of Lummus Technology (Houston, Tex.; www.lummustechnology.com) from McDermott International (Houston; www.mcdermott.com). Under the terms of the agreement, Lummus was valued at $2.725 billion.

PolyOne changes name following Clariant Masterbatches purchase

July 1, 2020 — PolyOne Corp. (Cleveland, Ohio; www.polyone.com) completed its purchase of the color masterbatch businesses of Clariant AG (Muttenz, Switzerland; www.clariant.com). PolyOne also announced that it has changed its name to Avient Corp. The Clariant Masterbatch business includes 46 manufacturing sites and technology centers in 29 countries, which will join Avient's Color, Additives and Inks business segment. The net purchase price is $1.44 billion.

BP to sell petrochemicals business to Ineos for $5 billion

June 29, 2020 — BP plc (London; www.bp.com) has agreed to sell its global petrochemicals business to Ineos (London; www.ineos.com) for a total consideration of $5 billion. BP's petrochemicals business is focused on two main businesses — aromatics and acetyls. In total, the businesses have interests in 14 manufacturing plants in Asia, Europe and the U.S., and in 2019 made 9.7 million m.t. of petrochemicals.

DSM to acquire a portion of Clariant's 3D-printing business

June 24, 2020 — Royal DSM N.V. (Geleen, the Netherlands) will take over certain parts of Clariant's 3D-printing business portfolio. The upcoming integration of these assets enables DSM to strengthen its engineering-grade filament, pellet and powder portfolio. The transaction includes part of Clariant 3D-printing team, a selection of their material portfolio and expertise in powder development, as well as a small production line. ■

Mary Page Bailey

Virus Countermeasures Drive Worker Safety

The COVID-19 threat has increased the urgency for implementing contagion-prevention strategies and controls for workers at industrial sites

IN BRIEF

Chemical process industries (CPI) companies are used to managing a range of worker health risks related to chemical exposure, extreme temperatures and noise, among others, but the global coronavirus pandemic has forced CPI facilities to elevate a broad set of infectious disease considerations to prominence among other process safety priorities. To reduce infection risk in industrial workspaces, companies are enhancing disinfection protocols, increasing use of respiratory personal protective equipment (PPE), implementing physical distancing at jobsites, relying on remote work, and other strategies. Industry consultants have provided some guidance for companies to use as they operate in the midst of a pandemic. Meanwhile, vendors and equipment providers have responded by introducing products to help reduce contagion risk in various scenarios.

Theresa McCollom, a certified industrial hygienist and environmental, health and safety consultant at the U.S. headquarters of Antea Group (St. Paul, Minn.; us.anteagroup.com) says that while the pandemic has impacted the chemical process industries unevenly — petroleum refining has seen reduced demand, for example, while chemical plants making ingredients for disinfectant formulations have seen a surge in demand — most companies and plant sites are taking whatever actions they can when it comes to preventing workplace infections. "Most employers in the industrial space are doing some sort of health screening, either asking questions for workers to self-report, or using thermal thermometers," McCollom says, and "most sites are doing some sort of workplace reconfiguration, where it is possible, such as putting up barriers, as well as cleaning high-touch areas."

Eastman Chemical Co. (Kingsport, Tenn.; www.eastman.com) senior vice president and chief manufacturing, engineering and supply chain officer Mark Cox confirms that there has been a sudden emergence of safety efforts focused on COVID-19 prevention at Eastman facilities. "We work with a zero-incident mindset in everything that we do, and this pandemic has been no different. We are doing all we can to keep our teams safe and healthy while still continuing to produce the critical products our customers need — many of which have been important in the battle against this virus."

To help companies protect workers in the face of public health threats, there are many new product offerings available from simple to complex, and targeting a variety of public health risks. McCollom says many of her clients are looking for evaluations of new products. "They are asking: Is this 'snake oil?'; Will this be effective?" she says. "Although there are many products that can help reduce public health risks, there are not really any 'miracle widgets' that can make the risks go away," McCollom says. "If product claims appear too good to be true, they most likely are."

Hazard exposure tools

For CPI sites, pandemic-related risks must be placed into a wider context of risk management. American Industrial Hygiene Association (AIHA; Fairfax, Va.; www.aiha.org) board member Nancy McClellan, the CEO of Occupational Health Management PLLC (Detroit, Mich.; www.oh-management.org), says "whether the hazard is chemical, physical or biological, hazard exposure and control banding (HECB) can assist organizations in wrapping their arms around the challenges of the hazard by identifying the highest risks and prioritizing the most appropriate solutions." HECB tools can also provide key performance indices to measure an organization's progress in mitigating the hazards, she notes.

To explain HECB in the context of COVID-19, McClellan says "In the case of a biological hazard, one needs to identify all of the relevant factors involved in risk. Since risk equals the likelihood of incidence multiplied by the severity of the hazard, we need to drill down to all of the factors influencing 'likelihood' and 'severity.'" Likelihood of exposure to COVID-19 can include social distancing practices, building operations and cleaning practices. Severity of the hazard depends on factors that can include age and comorbidities of the individuals, she continues. "Once these factors are identified, assigned a risk level and mathematically weighted, risk scores can then be calculated. The risk score then directs the HECB tool user toward potential solutions or controls for mitigating the hazard."

As an organization's risk scores are reduced with proven solutions, the tracking of the scores from year to year can clearly illustrate progress in risk mitigation, she adds.

At industrial plants, there is now "more of a three-way conversation among industrial health and safety officers, engineers and 'C-suite' leaders about how to allocate resources to where they will have the largest impact," McClellan says.

AIHA is among a number of industry associations and consulting firms that have issued guidance that is relevant to operating in chemical manufacturing plants with an added focus on public health safety. The AIHA has compiled a series of industry-specific plans for making workplaces as safe as possible. Other organizations that have come out with industrial workplace guidance include PPE supplier Protective Industrial Products Inc. (Latham, N.Y.; www.pipglobal.com), which has released the "PIP Essentials Safety Book," and business consulting giant McKinsey & Co. (New York, N.Y.; www.mckinsey.com), which published the article "Managing a Manufacturing Plant through the Coronavirus" online.

Workplace reconfiguration

One main pillar in the fight against COVID-19, in all settings, is maintaining physical separation among workers to reduce exposure to infectious particles. There are multiple strategies to achieve this including altering team structures and working methods to limit contact across the workforce. The McKinsey guidance states: "Minimizing the potential future impact of infections will require companies to alter team structures and working methods in order to limit contact across the workforce. One way this can be done is by establishing 'pods' for all on-site personnel, organized for self-contained teams with clearly defined tasks and workspaces that can be physically and socially separated from each other as much as possible."

Eastman, for example, is adapting this concept for its own sites. Cox says shift schedules at the company sites were changed to minimize the interaction between production crews and have minimized contact between production staff and others by restricting access to control rooms, for example, to only those needed for critical operations. The company has also used remote work where possible and works with employees to understand travel outside of the areas where they live and operate to reduce the spread of the virus upon return.

Mentioning another separation strategy, Dean Alcott, market development manager at RedGuard USA (Wichita, Kan.; www.redguard.com), says modular buildings, such as those offered by his company, can allow a quick and safe space to increase separation among workers. "Not only can we provide safe space close to the process hazards, but we can arrange it as needed for separation," Alcott says. "We also provide non-blast buildings, known as a SiteBox, that can be quickly available and are very flexible, allowing workers to spread out on job sites."

Connected technologies

Social distancing strategies can also be supported with modern industrial internet of things (IIoT) technologies. EmbedTek LLC (Waukesha, Wis.; www.parirange.com) has introduced

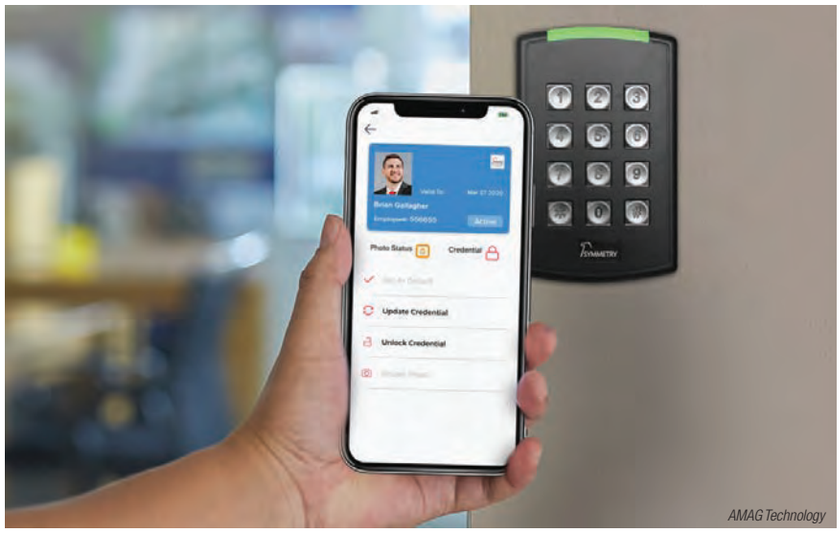


FIGURE 1. The Symmetry Mobile product for access management allows users to credential visitors and workers for access to various areas in a way that does not require any in-person contact

PariRange, a peer-to-peer social distancing and contact-tracing device.

Employees wear the PariRange device, which monitors the distance from other devices. Ultra-wideband and time-of-flight technology measure distance between devices with a rated accuracy of four inches. When an employee comes within six feet of another device, PariRange sends a vibration alert. Date and duration of close contacts are recorded whenever multiple devices come within the 6-ft range. Each day, the duration of close contact a user's device has with other devices is aggregated and stored for 14–28 days. Data are easily viewed through a PariRange Log Reader, which can be connected to a computer via USB, or placed throughout a facility to pull data from employee devices automatically as they walk by.

If an illness occurs, the device can identify employees who have had close contact with the infected individual. This allows businesses to take action quickly and follow recommended protocols to curtail infection spread, the company says.

With the pandemic forcing many plant employees to work from home, there is an increased need to get timely safety diagnostic information remotely. Fire and gas safety system solutions provider Det-Tronics (Minneapolis, Minn.; www.det-tronics) offers an example of this. Det-Tronics systems product manager William Crosley says "Because travel and on-site field visit restrictions have limited the number of people on plant sites, integrating the process control and life-safety systems can be critical. A certified, documented fire and gas safety system that can communicate appropriate messages to the process control and emergency shutdown systems enables the plant to monitor both systems' parameters simultaneously through fixed and remote-operator stations. When integrated with the process control system, Eagle Quantum Premier fire and gas safety system can provide continuous real-time status of its flame and gas detection devices as well as the suppression system."

Access management and health

Access to industrial sites has always been a priority from a security perspective, but the public-health concerns have added a new dimension. A new technology product that is addressing this area is Symmetry Mobile (Figure 1), a product developed by AMAG Technology Inc. (Hawthorne, Calif.; www.amag.com). Symmetry Mobile is an internet application that lets its users credential visitors without necessitating any in-person contact. It provides full central control over credentials, photos, devices and configuration all from the app, including multi-factor authentication.

"By using a smartphone instead of access cards, a site can eliminate the need to visit a badging office and stand in line to physically interact with security staff," explains AMAG product director Johnathan Moore.

AMAG provides both software and hardware for the system, which can manage access to various areas of a plant site to visitors, Moore says. Symmetry Mobile allows central management of the credentials, photos and devices remotely.

Adding another dimension to access-management systems are recently launched products that can support building entry with health screening systems that can detect elevated body temperatures. Among them is the Siveillance Thermal Shield (Figure 2) from Siemens AG (Munich, Germany; www.siemens.com). This package quickly measures the body temperature of a person seeking to access a building and enables the results to be integrated into the video and access systems of corporations. Thermal imaging cameras are used to measure, in a contactless way, the body temperature at a distance of up to two meters, ensuring the safety of monitoring staff. If the camera screening indicates an elevated body temperature, a second reading must be taken using a medical thermometer to confirm the finding.

In July, Honeywell Performance Materials and Technologies (Houston; www.honeywell.com) announced a complete, modular software solution to help industrial companies enforce compliance with key health and safety requirements as their employees return to the workplace, including body temperature checks and automated entry management processes.

The system leverages the company's existing digitized workforce platform, and facilitates site monitoring compliance in accordance with social distancing policies. It also enables contact tracing and monitoring of worker safety and includes remote collaboration capabilities to empower company operations with a reduced workforce.

The system can support Honeywell thermal cameras that can be used with systems compliant with NDAA 2019, Section 889 to check

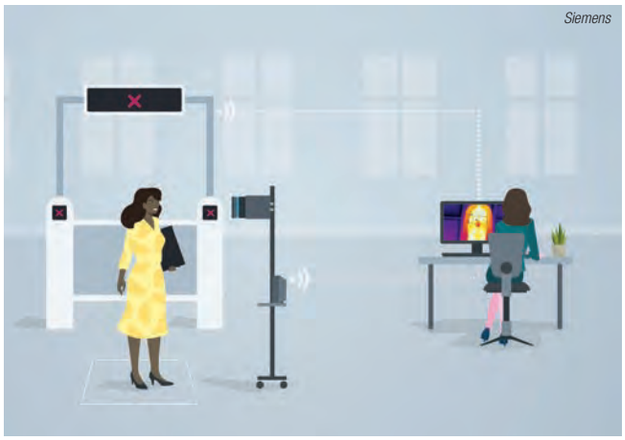


FIGURE 2. Body temperature of individuals entering buildings can be measured by the Siveillance Thermal Shield

for elevated body temperatures and provide input to the access control system. This can enable operators to restrict entryway access if an elevated temperature is detected helping to automate the preliminary screening process and reducing manual tasks, the company says.

FLIR Systems, Inc. (Arlington, Va.; www.flir.com) recently announced the multi-application FLIR A400/A700 Thermal Smart Sensor and Thermal Image Streaming fixed cameras. FLIR designed the A400/A700 cameras with two configurations, one of which is recommended for measuring elevated skin temperatures. It incorporates advanced measurement tools and alarms with edge computing to enable faster critical decisions, FLIR says.

Eastman's Mark Cox comments that along with social distancing, good hygiene practices, enhanced cleaning protocols and mask wearing, temperature screening has been a part of keeping teams healthy at Eastman facilities.

Respiratory PPE

Since the onset of the pandemic, respiratory PPE has been an important tool for reducing disease spread. Because new cohorts of workers that previously had not used respiratory PPE, such as N-95 respirators (filtering 95% of airborne particles), now required it, the demand for this type of PPE has been surging. Although the industry responded with increased supply this summer, there remains stress on the supply of N-95 masks, especially in the medical sector. Because of this, industrial sites seeking to equip workers with N-95 masks should look at the full range of N-95 respirators, such as re-usable elastomeric respirators, suggests Charles Johnson, president of the International Safety Equipment Association (ISEA; Arlington, Va.; www.safetyequipment.org), a trade association for safety equipment manufacturers. "The medical community remains somewhat hesitant on reusable elastomeric N-95 masks, because, for example, those with exhalation valves cannot be used in most medical settings," Johnson says, "But these types of respirators can be a viable alternative for use by personnel in industrial settings." 3M, Honeywell and MSA Safety are among the several manufacturers supplying this type of reusable mask.

HVAC and ventilation

Studies investigating the transmission of the novel coronavirus have pointed to the importance of indoor air ventilation. The Association of ASHRAE Epidemic task force recently developed guidance on mitigating potential health risks during reopening of buildings closed during the COVID-19 pandemic.

"Key elements of a strategy to limit the spread of the COVID-19 virus are to perform needed heating, ventilating and air conditioning (HVAC) system maintenance, including filter changes, and to run HVAC equipment, prior to re-occupancy," says ASHRAE Epidemic Task Force chair Bill Bahnfleth.

Disinfection

Cleaning in industrial settings has also received renewed focus in the pandemic, and disinfection solutions have become more widely used, especially in high-traffic areas and on high-tough surfaces. Madison Chemical Co. Inc. (Madison, Ind.; www.madchem.com) recently provided research confirming the effects of its 4-chain quaternary surface sanitizer on the novel human coronavirus. Madison Chemical's Brad Sims says MADISAN 75 disinfectant, mildewstat, and virucide for hard, non-porous, and inanimate surfaces is ideal for a wide variety of installations, including industrial and manufacturing environments. ■

Scott Jenkins

Cumene Production from Benzene

By Intratec Solutions

Cumene (also known as isopropylbenzene) is an organic compound of the aromatic hydrocarbon class. It is a colorless liquid, insoluble in water, but soluble in most organic solvents. The production of cumene grew rapidly during World War II, when this aromatic compound was used as a component of aviation fuel.

Today, cumene is mainly employed as an organic solvent in pharmaceutical manufacturing and as a flow-control agent for thermoplastic elastomer processing. Cumene derivatives (mainly phenol, acetone, and methyl styrene) are compounds with many chemical and industrial uses. Currently, the production of cumene is largely associated with the demand for phenol and phenol derivatives.

The process

The present analysis discusses an industrial process for cumene production. The process has two main sections: (1) reaction; and (2) distillation.

Reaction. In the reaction section, there are two reactors: the alkylation reactor and the transalkylation reactor. Fresh refinery-grade (RG) propylene and recycled benzene are mixed and fed to the alkylation reactor. In addition to the cumene product, the alkylation reactor effluent comprises unreacted benzene, non-reactive propane (present in the propylene feed), side products polyisopropylebenzenes (PIPB) and heavy ends. The effluent is routed to the depropanizer column in the distillation section. The transalkylation reactor, in turn, is fed with recycled benzene and PIPB recovered in the distillation section. In the transalkylation reaction, PIPBs are reacted with benzene to form cumene. The transalkylation reactor effluent is routed to the benzene recovery column in the distillation section.

Distillation. In the distillation section, a depropanizer column removes non-reactive propane from the alkylation reactor effluent. The propane-free reaction effluent is routed to the benzene-recovery column, while propane is purged from the process. The benzene-recovery column is also fed with fresh benzene and the product of the transalkylation reactor. Benzene is separated and recycled to the reaction section of the process, while a crude cumene stream, obtained from the bottom of the column, is routed to the cumene-purification column, from which high-purity product is obtained. The impurities rejected in the cumene column are treated in a further column, which recovers PIPB for the transalkylation reaction.

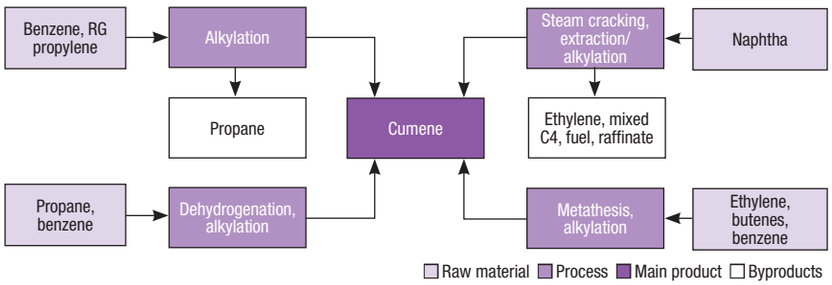


FIGURE 2. Multiple pathways exist for cumene production

Production pathways

The two main starting materials for cumene manufacture are benzene and propylene. Benzene and propylene are reacted via alkylation to produce cumene. Polyisopropylbenzene byproducts can be reacted with additional benzene via transalkylation to enhance cumene yield. Figure 2 presents different pathways for the production of cumene.

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce cumene was about $750 per ton of cumene in the third quarter of 2016. The analysis was based on a plant constructed in the U.S. with the capacity to produce 300,000 metric tons per year of cumene.

This column is based on "Cumene from Benzene and RG Propylene (Zeolite Catalyst) – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/cumene-production-cost. ■

Edited by Scott Jenkins

Editor's note: The content for this column is supplied by Intratec Solutions LLC (Houston; www.intratec.us) and edited by *Chemical Engineering*. The analyses and models presented are prepared on the basis of publicly available and non-confidential information. The content represents the opinions of Intratec only. More information about the methodology for preparing analysis can be found, along with terms of use, at www.intratec.us/che.

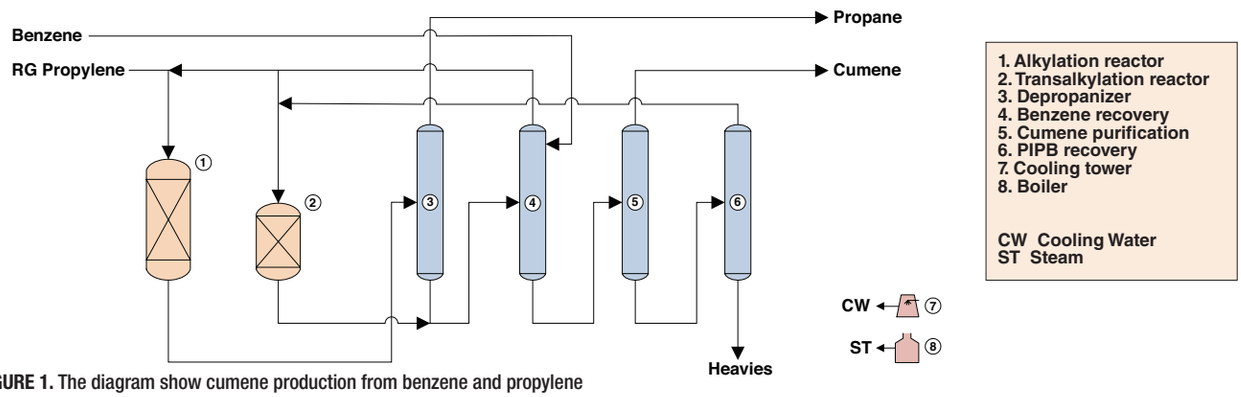


FIGURE 1. The diagram show cumene production from benzene and propylene

Heat-Transfer-System Maintenance During Slow Periods

Department Editor: Scott Jenkins

Periods of reduced heat-transfer-fluid (HTF) system operation offer opportunities for mechanical integrity engineers to perform necessary maintenance. Here are suggestions for using the downtime for maintenance tasks.

Safety

These activities support ongoing safety of the HTF unit.

Leak repairs. Repair wet insulation and underlying leak points to help avoid potential fires. Repack valve stems, replace gaskets and make repairs to flange-pairs where temporary injectable sealant was used.

Equipment repairs or replacement. Use proper process-entry and lockout/tag-out permitting procedures for equipment to be properly prepared for repair or replacement.

Sample port installation. This requires tie-points for high-pressure inlet and low-pressure return, and a means for cooling fluid for collection.

Fire safety equipment checks. Check handheld fire extinguishers, monitor nozzles, safety showers, sprinkler systems and the gas sparge for the heater firebox.

Restock area safety supplies. Replace used spill-response kits and oil-drying media, gloves and first-aid supplies. Ensure that supplies are not expired and are in usable condition.

Preventive maintenance

Preventive maintenance (PM) and integrity-assurance checks are best accomplished while systems are down.

Inspections. Evaluate area switch gear, pressure-relief devices, heater coils or burners, thin-walled expansion joints or flex-hose, utility systems such as cooling water, instrument air or nitrogen, barrier fluid systems, lubricant checks and top-ups. For pumps and heaters, see the manufacturer-issued inspection and PM guidance.

Calibrations. Conduct periodic checks of liquid level instruments and flowmeters, critical interlocks, pressure sensors and transmitters to ensure proper control of HTF temperatures and protect HTF life.

Mechanical integrity checks. Vibration monitoring and repair, vessel inspections for corrosion and wall thickness, and proper operation of the inert-gas blanketing system

Alignments. Alignment checks for motor shafts of rotating equipment, including pumps, blowers and fans

System flushes and cleaning. Poor performance may be due to system deposits. Consult the fluid manufacturer for the best cleaning option. For HTF side cleaning, keep fluid and system compatibility in mind. If the activities require outside resources, schedule appointments in advance.

Fluid servicing

Recent fluid analysis results should be discussed with your HTF technical expert in advance of shutdown periods to determine what actions might be necessary to ensure uneventful ongoing operations. Observations should include looking for elevated acidity, unusual or large amounts of solids, contaminants, and degree of thermal degradation present.

Fluid sampling for quality check-up. Collect a representative (that is, well-circulated) sample for analysis. Samples should be cooled to less than 200°F and promptly sealed for proper assessment. Review questions around proper sample collection with the fluid manufacturer, and discuss the results and any recommendations made in case planning for action is required.

Filters/strainers. Filters operate full-time, and continually collect debris. Replace or clean filter elements and pump-suction strainers, if needed. Examine the debris for any unexpected materials; this can indicate in-service materials that are incompatible with the HTF. For systems without filters, commercial filtration service providers are available. If connections to and from the HTF system are required, identify connection points, or plan to have them added.

Fluid quality improvement via partial to full replacement. Poor fluid quality can require different measures, including venting, drying of excess moisture, filtration, dilution or even replacement. Getting the analysis in-hand prior to shutdown can enhance opportunities for problem resolution prior to restarting. If new fluid or support services are required, make arrangements for during a shutdown.

Dispose of 'light ends.' Organic vent condensate from HTF systems will require drumming out and proper disposal. Consult with site waste-management supervision for assistance.

General

Routine area maintenance can fall to the bottom of the priority list, but downtimes can allow catching up on these important tasks:

Housekeeping. To improve operational effectiveness, oily residues should be cleaned from walkways, structural steel, siding, equipment and piping to reduce fire risk. Downtime allows a chance to put equipment, tools, buckets, hose and others back in place, if needed.

Line labeling. Pipe racks can become congested, which makes tracing pipeline routes difficult. Line labeling and direction-of-flow arrows can help. This includes HTF piping as well as process and utility piping. Ordering the labels in advance is advised.

Equipment/valve labels and tags. Vessel labeling is an OSHA requirement, but labeling of valves and minor equipment can also be helpful to operators and mechanics, as well as aiding training programs.

Tie-ins for future needs. Potential needs for piping modifications can include tie-points for new circuits, piping upgrades, additional or new instrumentation, repairs to old piping, and addition of thermal expansion loops. These should all require engineering planning in advance of the shutdown to ensure system specifications are properly met.

Training. Operator training should involve an in-depth review of the system, its components, flows and controls while the system is down. ■

Editor's note: Content written by Conrad Gamble, Eastman

Focus on Solids Handling

This bulk-bag conditioner has a rotary lift platform

The new hydraulic bulk-bag conditioner with rotary lift platform (photo) quickly and safely returns solidified materials in bulk bags to a free-flowing state. The operator loads the bulk bag into the unit via forklift and activates a conditioning sequence controlled by a programmable logic controller (PLC). Twin pivoting conditioning arms with extended travel penetrate deeply into the material for effective results. A robust hydraulic rotary-lift platform positions the bulk bag during the conditioning sequence, ensuring the bag is thoroughly conditioned from top to bottom. Patented design returns even the most severely agglomerated materials to a free-flowing state. Units are custom designed. — *Material Transfer and Storage, Allegan, Mich.*
www.materialtransfer.com

This diverter valve has many new features

The second-generation of the PT45 diverter valve (photo) introduces new features, such as adjustable alignment stops located in the housing, position indication from the tunnel itself, additional actuation options and external tunnel-position indication. A positive food-grade rubber-silicone seal at each port is designed to help prevent contamination. Additional features include 45-deg port-to-port rotation; a two-way switching capability for either dilute phase or dense phase conveying applications; cast iron or aluminum housing, tunnel, and end plates with a 316 stainless-steel actuator and arm assembly; and inlet and outlet ports flanged to mate 150# ANSI flange patterns. — *Schenck Process LLC, Whitewater, Wis.*
www.schenckprocess.com/us

Non-binding wire design promotes screening efficiency

Over the years, screen blinding and pegging have been barriers to efficient material screening that processors have sought to overcome via a variety of half-measure solutions. Now, this company recently launched its Klear-Screen series panels to solve these problems. The series (Styles S, M and W; photo) design features spaced wire-cloth urethane strips that essentially operate as live moving wires to create more throughput to dislodge materials. Ultimately, the resulting near-size particles will not blind the screens. — *Midwestern Industries, Inc., Massillon, Ohio*
www.midwesternind.com

Unloader uses 'regulated vibration' for discharging

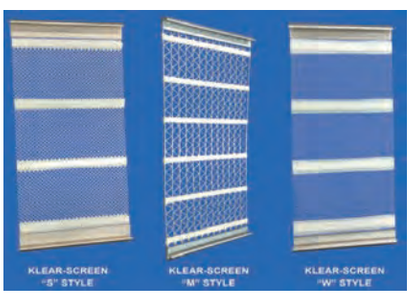
The new Model 821 Bulk Bag Unloader (photo) provides, a safe, dust-tight and highly effective means for discharging a wide assortment of dry solid materials from within bulk bags of various sizes, typically for use in conjunction with this company's metering equipment. In operation, positive product discharge is reliably achieved by means of regulated vibration uniformly applied to the body of the Model 821 Unloader, and in turn to the bulk bag. The vibratory action is produced by an adjustable heavy-duty motorized vibrator, powered by a totally enclosed, non.vented (a.c.) motor. When energized, powerful flow-inducing vibratory forces transfer from the body of the unloader into the bag and the material contained within, effectively and efficiently discharging its contents. An independently mounted iris valve with the company's Bag Spout Untie Receptacle is attached beneath the unloader and flexibly connects to the outlet of the unloader. The outlet of the Untie Receptacle typically connects to auxiliary process equipment for a totally dust-tight assembly. — *Acrison, Inc., Moonachie, N.J.*
www.acrison.com

Reverse-lift mixers with CIP and purged controls

The Double Planetary Mixer is available in a reverse-lift design that raises the vessel to the mixing position, rather than lowering the agitator assembly. A reverse lift facilitates improved rigidity and more uniform blade-to-vessel clearances without relying on the floor to be completely level. Four of eleven such re-


Material Transfer and Storage


Schenck Process



Midwestern Industries


Acrison

Charles Ross & Son

verse-lift model DPM-100 mixers (photo) were recently built for a single end user. Two interchangeable mixing vessels are supplied with each machine to form a semi-continuous mixing operation. Double Planetary Mixers can process both wet (pastes and slurries) and dry (granulations and powder blends) applications, including semi-solids (gels and dough-like materials). The 100-gal mixers feature an elaborate clean-in-place (CIP) system, which includes a total of five ports with rotating spray nozzles directed at the gearbox, agitators and vessel. Each mixer is controlled from a NEMA 4X stainless-steel purged panel (Class I, Div 1, Group D). The entire fleet of eleven machines is explosion-proof. — *Charles Ross & Son Co., Hauppauge, N.Y.*
www.mixers.com

Flexicon

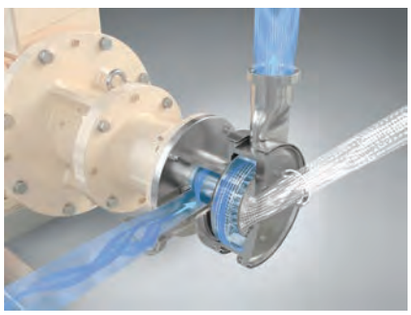
An ultra-high capacity bag-filling system

A new sanitary bulk-bag filling system (photo) features dual Swing-Down fillers fed by high-capacity weigh hoppers, achieving fill rates of up to 40 bulk bags per hour. The patented filler design simultaneously lowers and pivots each fill head into a vertically oriented position that places the inflatable spout connection collar, inflator button, and four bag-loop latches within reach of an operator standing on the plant floor. This significantly increases the safety and speed of connecting bulk bags, because the operator can connect each bag loop and the bag spout without having to stand on a ladder or reach over equipment to secure the bag. The all-stainless-steel system is finished to sanitary standards and equipped with a NEMA 4X controls enclosure, allowing wash-down. — *Flexicon Corp., Bethlehem, Pa.*
www.flexicon.com

Vibra Screw

Partners launch a smart belt-cleaning monitor

Together with partner Uptake (Chicago, Ill.; www.uptake.com), this company recently introduced Flexco Elevate Belt Conveyor Intelligence, a realtime belt-cleaner monitoring system that harnesses the power of predictive analytics to remotely gather critical insights that optimize belt conveyor productivity and heighten operational efficiencies. Flexco Elevate allows for the remote monitoring of belt cleaners via a wireless platform. Data collected from belt cleaners are transferred into insights, delivered to an intuitive cloud-based dashboard. The easy-to-use platform is designed to simplify and accelerate belt maintenance using its powerful, data-driven engine. — *Flexco, Downers Grove, Ill.*
www.flexco.com



ystral

Spiral elevating conveyor handles hot catalyst

This company is providing an 18-in. spiral conveyor (photo) for the elevated transfer of various hot (~400°F) catalysts extrusions coming off a rotary calciner. The heat of the material causes severe maintenance problems when using a bucket elevator, resulting in unacceptable downtime. This Spiral Conveyor moves material vertically, solely through the action of twin external vibrators with no internal moving parts. It eliminates the heat-related maintenance problems of the bucket elevator with its many parts and also helps cool the material prior to the next process point. This machine is fabricated of 316 stainless-steel material-contact surface and includes a heat-resistant paint finish on external steel parts. — *Vibra Screw, Inc., Totowa, N.J.*
www.vibrascrew.com

Achieve complete wetting without forming agglomorates

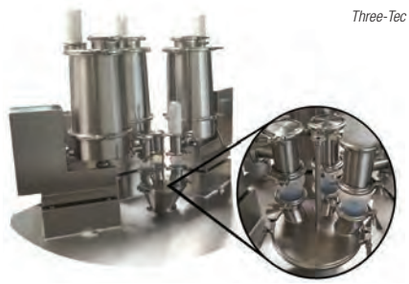
The Conti-TDS (photo) achieves the complete wetting and optimum dispersion of powder particles, both in liquid and viscous media. It is used, for example, in the manufacture of all solvent-based and watery coating suspensions. The powder is added via a suction hose from bags or directly from containers. The powder only comes into contact with the liquid in the dispersion zone (photo). The dispersion takes place under a massive shearing action and vacuum. The Conti-TDS generates its suction effect directly in the liquid. This means that contact between the operator and the materials is completely avoided. — *ystral GmbH, Ballrechten-Dottingen, Germany*
www.ystral.de

This solids-dosing system is accurate and flexible

The new modular, multi-dosing system (photo, p. 19) from this company is suitable for accurate powder dosing of active pharmaceutical ingredients (APIs) and excipients in the process of

solid-dosage production. Up to eight different dosing units, each designed to specific product characteristics, such as feedrate, accuracy and flow behavior, are modularly configurable according to user requirements. The multi-dosing system can be executed for

Three-Tec



continuous production processes with refilling units, as well as for traditional batch procedures. High-accuracy dosing results, also with hardly flowing and cohesive powders, are essential for a repeatable process and further steps, such as mixing/blending, granulation, hot-melt extrusion, drying, direct compression and coating. Depending on the diameter and design of the screws, outputs from 0.005 kg/h up to 1,000 kg/h can be achieved. — *Three-Tec GmbH, Seon, Switzerland*
www.three-tec.ch

Nickel-handling system has a V-shaped hopper

This solids-handling specialist has supplied Brighouse-based project engineering, design and consultancy service provider, Projex Solutions Ltd. with a handling system comprising a collecting hopper and a screw conveyor for transferring nickel and nickel-oxide powder. The nickel-handling system (photo) collects the powder from a kiln gas cyclone. The mild steel hopper is V-shaped and

Ajax Equipment

steep-walled for best flow behavior. The collecting screw features both left and right-hand flights for efficient central discharge. Nickel is a fine, highly dense powder, making it highly abrasive. To mitigate the resulting wear, the flights of the screw have been treated with a hard-wearing coating. — *Ajax Equipment Ltd., Bolton, U.K.*
www.ajax.co.uk

A system for micro and tote batching

Customized ingredient-batching systems with both liquid and dry materials (photo, p. 20) are now available. Each automatic Micro and Tote Batching System is custom designed and manufactured to meet the specific needs and requirements of the user for batching both liquid and dry materials. These systems typically include supply bins, feeders, work platforms, automatic or manual bin refilling, liquid tank/pump skid equipment and the dry and liquid dosing

Systems & Controls

Best Process Solutions

Martin Engineering

Palamatic Process

Van Tongeren America

automatic control system. Optional equipment may include raw-material bag-lift handling equipment, dust collection/control for high-dust dry materials, batch material conveying equipment (such as mechanical drag conveyor), lot tracking and traceability, barcode scanning and RFID scanning. Other customized options can also be included. Micro weighing systems are those that have scale weighments up to around 50 lb. Larger weighments are known as Minor (from 50 to 100–150 lb) and Major (>150 lb). — *Systems & Controls, Inc., Sterling, Ill.*
www.sterlingcontrols.com

These vibratory belt conveyors are durable

The Vibratory Belt Conveyors from this company are durable bulk processing-equipment conveyance systems for moving products. These vibratory belt conveyors are highly customizable depending on the user's manufacturing needs. Available in various lengths, the units can be tandem-mounted in series for longer lengths as needed. Design features include safety side panels/guards; two counter-rotating motors (230/460 V, 3 phase, 60 Hz); UL controls available; can have up to four vibratory tables; and tubular trough construction. — *Best Process Solutions, Inc., Brunswick, Ohio*
www.bpsvibes.com

A new conveyor belt-cleaner design, with cut-to-length

A new conveyor belt-cleaner has been designed with an innovative method of holding the urethane blade in place without the need to mill any slots for holding pins. Combining the benefits of previous designs into one product, the QC1+ Belt Cleaner (photo) can be cut to length to fit virtually any application, reducing the need for customers to stock multiple blade sizes to accommodate different belt widths. Operators simply trim the blade to the desired size from the stock 9-ft (2.74-m) length to match the material path, slide in the blade holders and lock them in position. The new blade can be retrofitted to virtually any of this company's main frame and most competing designs. Five different urethane formulations are currently available for the QC1+. — *Martin Engineering, Neponset, Ill.*
www.martin-eng.com

Contained glove-box bag-dump station for hazardous materials

The SackTip SE bag dump station range (photo) is designed to fully contain hazardous dust for the feeding of powders and bulk solids into a manufacturing process. Design features include: infeed roller conveyor for bags and sacks; glove box for bag handling and opening operation; discharge hopper; integrated dust collection with jet pulse; and integrated sack compactor for waste volume reduction and containment of residuals. The sack tip trays can be manufactured in mild, 304 or 316 stainless steel with optional mirror polish on internals. The company can further design this equipment to meet strict ATEX and Class/Div. hazardous area requirements. — *Palamatic Process Inc., Philadelphia, Pa.*
www.palamaticprocess.com

Classification system separates at dual cut points

A clever upgrade from classifiers limited to a single cut point, the Dual Classification System (photo) enables processors to separate feed materials into three different product streams instead of just two product streams to meet gradation specifications for multiple products and help convert material discarded as waste into saleable product. Devised for classifying cement, limestone, asphalt sand, filter sand and other aggregates, the Dual Classification System integrates the company's Gravitational-Inertial Classifier (GIC) with its Centrifugal Classifier (CC) to separate the feed material at any cut point from 300 µm to 63 µm (50 to 230 mesh) during the initial pass, then at any cut point between 100 µm to 15 µm (950 to 150 mesh), all with a uniform distribution. The Dual Classification System is custom-designed and manufactured for each installation to meet target production goals and material specifications. The system is proven to perform continuously in unattended, continuous operation. — *Van Tongeren America, LLC, Lebanon, Pa.*
www.van-tongeren.com

A modular system for fine grinding

The HIGmill Plant (HMP; photo) is a standalone fine-grinding solution that consists of a HIGmill unit and pre-engineered auxiliary equipment

Outotec

modules. This approach reduces engineering, delivery, construction and commissioning time and cost while still providing a safe solution with the flexibility to meet various process, layout and regulatory requirements. The system offers a space-efficient footprint with flexible modules that can be arranged according to plant layout. Other benefits include: optimized delivery lead time and site construction planning; dedicated switch room control; optional media-handling system guarantees easy shutdown and improved safety; and shipped pre-assembled for superior quality, minimum fabrication risk, and lower construction costs, says the company. — *Outotec Oy, Espoo, Finland*
www.outotec.com

This new vibratory feeder handles heavy applications

The 76 Series Vibratory Feeder (photo) — the largest model in this company's line up of vibratory feeders — supports

Eriez Manufacturing

trays up to approximately 200 lb, and is offered in most common voltages. In designing this powerful and unique feeder, the company filled a void in the marketplace by providing a feeding solution for applications where trays are often too heavy for smaller models and using multiple drives is not practical. Large bucket elevators require high-capacity feeders with long tray overhangs to reach the in-feed section of the elevators, making the 76 Series Vibratory Feeder an ideal choice. With its ability to easily handle larger trays with multiple features such as screens, covers, inlet spouts and downspouts with a single compact drive unit required by bulk bag dischargers, the system is also well suited for bulk bag unloading. — *Eriez Manufacturing Co., Erie, Pa.*
www.eriez.com

A new discharge station for big bags

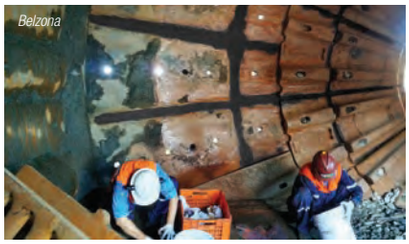
The Big Bag Unloader (BBU; photo) enables food, chemical, pharmaceutical and other powder processors to safely discharge materials from bulk bags into hoppers, feeders, reactors, sending vessels, conveyors and to other stages in the process. Developed to promote consistent product flow and reduce material waste in a safe work environment, the BBU features a proprietary, twin-ring, dust-tight docking station that creates a sealed, dust-free connection linking the bag bottom to the process. With a single worker managing the operation, the bulk-material-transfer system virtually eliminates ambient combustible dust, along with its inherent safety risks, says the manufacturer. The bulk-bag discharge station offers a wide range of process interfaces, flowability equipment, dust containment systems and loading infrastructures in a choice of mild or stainless steel as standard. — *Gericke USA, Inc., Somerset, N.J.*
www.gerickegroup.com

Gericke USA

A new innovation in abrasion resistance

This company has released a new material that is aimed at making light work of big areas. The product Belzona 1814 has been formulated to resist the harshest abrasive environments typically found in the mining, cement, pulp-and-paper, biomass and other industries. This epoxy-based material can be applied with a brush (photo) or a float to protect assets by preventing metal loss and subsequent downtime,

Belzona



either on its own or as part of a system with alumina tiles. Supplied in 30-kg units, compatible with mechanical mixers and boasting a long working life, Belzona 1814 is most suited for application to large assets, including chutes, hoppers and screw conveyors. — *Belzona, Inc., Miami, Fla.*
www.belzona.com

Compact air conveyors with no moving parts

Air Conveyors, also known as air hopper fillers, are a convenient way of moving powdered or granulated products around a factory, and a new range of these types of products has been introduced by this company (photo). These compact conveyors offer important advantages over conventional conveyors, such as no moving parts, high reliability and easily controllable flow. The conveyors work by converting a compressed-air stream into a strong moving air

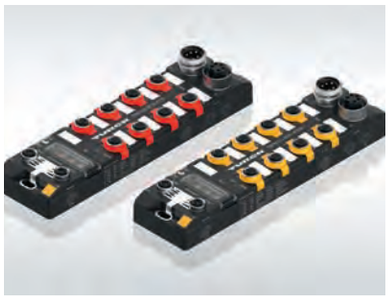
The Air Nozzle People

current with a partial vacuum at one end and a positive air flow at the other. This allows light product to be moved through a tube system with no moving parts and no external power source other than the compressed air feed line. They are available in a range of materials including hygienic 316 stainless steel for food-grade applications and in several different sizes to fit pipework from 3/8 up to 5 in. Also, an XS-PC option is available as a clog resistant conveyor, which is suitable for moving materials that may be prone to clogging conventional conveyors. — *The Air Nozzle People, Newark, Notts, U.K.*
www.airnozzle.co.uk

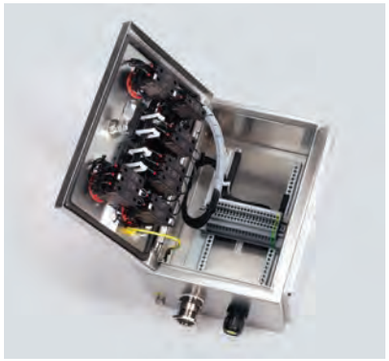
Gerald Ondrey

New Products

Rembe



Hans Turck



R. Stahl

Wilden Pump and Engineering

The next evolutionary level of explosion protection

Similar to a process control system, the iQ Safety Cockpit offers an overview of all relevant protective and equipment system status, which can also be monitored in real time from any location remotely via a smartphone. Detailed, automatic and semi-automatic action plans can be linked and initiated with this system. If an event occurs in a certain area, sending an email or an SMS text message to a pre-defined distribution group can be automated to bring the incident to their attention (photo). For example, in the event of an explosion, the responsible safety officer might be informed by text message via a service phone, the surveillance cameras in the affected area could be activated or set to a different mode and management would receive an email. The iQ Safety Cockpit guides the logged-in user through the pre-defined plan of action. — *Rembe GmbH Safety + Control, Brilon, Germany*
www.rembe.de

Ethernet safety I/O modules with IP67 protection

The TBIP and TBPN full safety block input/output (I/O) modules (photo) control safety applications directly from the field and thus simplify modular machinery for Profisafe and CIP Safety, respectively. The robust IP67 modules provide safety input and output signals directly from the field to the safety controller. The modules can alternatively be used as decentralized safety controllers in the field. This function optimizes modular machinery and also applications in which long bus cycle times to the central controller would require greater safety distances. — *Hans Turck GmbH & Co. KG, Mülheim an der Ruhr, Germany*
www.turck.com

A space-saving innovation for control boxes and cabinets

With this company's new cover-installation concept for Ex control boxes and cabinets, users can install components directly onto the backside of the enclosure cover (photo), rather than on mounting rails deep in the control stations. Enclosures that are equipped in this way are said to be very easy to maintain. Actuators and control elements positioned underneath them, which are fitted directly to the captive hinge cover so that they are accessible, can also be easily replaced. In just a few steps, the contact blocks and LED pilot lights can be positioned safely and precisely underneath the actuator and can be wired and controlled conveniently from below. — *R. Stahl, Waldenburg, Germany*
www.r-stahl.com

Remote, IoT-enabled monitoring of AODD pumps

SafeGuard (photo) is an IoT-enabled (internet of things) pump-monitoring system that remotely tracks, records and alerts users to key performance indicators — such as leak detection, stroke rate and total stroke count — of air-operated double-diaphragm (AODD) pumps during operation. It provides realtime alerts via SMS or email to indicate any noteworthy change in operations that may be a precursor to or indicators of component failure. SafeGuard also provides the ability to store maintenance records to help identify patterns to further enhance preventative maintenance plans. SafeGuard has been designed to monitor a single pump or a fleet of AODD pumps within one dedicated software system. The connected SafeGuard system is composed of a single battery-powered sensor mounted directly onto the pump. This sensor collects and analyzes pump-performance data in real time and transmits it to a central gateway for encryption and transmission to the Cloud, where it can be accessed through a secure smartphone app or online portal. — *Wilden Pump and Engineering Co., Grand Terrace, Calif.*
www.wildenpump.com

A device for smart time-control applications

The new multifunctional MACX-TR timer relays (photo) make simple time-control applications smart. The combination of push-buttons and innovative OLED display allows easy operation directly at the device. As an option, NFC communication and the smartphone application (app) provide further setting options, such as the simultaneous

Phoenix Contact

configuration of several devices. Shutdown and switch-on times can be set precisely using the intuitive menu navigation system. Specific time values save the need for converting and checking the entries. Moreover, password protection prevents unauthorized access. The devices, at just 22.5 mm, are available either with screw connection or push-in connection technology. — *Phoenix Contact GmbH & Co. KG, Blomberg, Germany*
www.phoenixcontact.com

A laboratory mixer for high-containment applications

This company has built the smallest machine in its company history in order to meet the highly specialized demands of the high-containment segment. The new Ploughshare laboratory mixer type L1 (photo) supplements the L series and has a drum volume of only one liter. Thanks to its small drum and an angle drive, it is incredibly compact. Moreover, all components are easy to remove, meaning that wear parts in particular, which must be inserted into the glovebox through an airlock, are easy to replace and reinstall. The compact Ploughshare laboratory mixer is a special addition to the L Series. L Series machines are designed for development and small batch production and are available in several sizes, with drum volumes generally ranging from 5 to 50 L. — *Gebr. Lödige Maschinenbau GmbH, Paderborn, Germany*
www.loedige.de

Gebr. Lödige Maschinenbau

Diesel-tank level transmitters for oil-and-gas applications

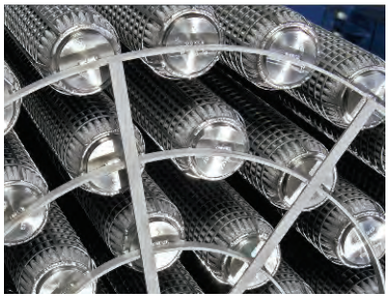
The Model 575 intrinsically safe level transmitter (photo, p. 24) and the Model DDMC meter/controller can continuously monitor the fuel level in diesel storage tanks. The Model 575 level transmitter is placed in the liquid, and an optional conduit adapter is used in the tank to protect the cable. The Model DDMC meter is used to power the Model 575 transmitter through approved electrical barriers. The DDMC also provides a continuous display of the level in the tank. The Model 575 submersible level transmitter is a hydrostatic level product for quick, reliable level measurement. It comes standard with CSA Intrinsically Safe approvals for many different level-monitoring needs, including lifts stations, inventory tank measurement, landfills, reservoirs or

Ametek U.S. Gauge

Flexim

Otek

Pfeiffer Vacuum



Porvair Filtration Group

any type of water-treatment facility. — *Ametek U.S. Gauge, Horsham, Pa.*
www.ametekusg.com

Non-intrusive measurement of very low liquid flows

The Fluxus F721 XLF (photo) is a non-intrusive ultrasonic flowmeter designed to provide precise measurement of flowrates of 3 L/h and below in small pipes with diameters from 10 to 50 mm. Since the clamp-on transducers are mounted on the outside of the pipe, meter installation and commissioning can be achieved without causing any interruption to the process. Furthermore, the external flow-measurement system works independently of pipe-wall thickness and pressure ranges and does not cause pressure loss. As the measuring device does not come into direct contact with the flowing media, it is not subject to wear and tear. This results in lower operational costs over the entire lifecycle and increased operational and environmental safety because risk of leakage is ruled out. — *Flexim GmbH, Berlin, Germany*
www.flexim.de

New PLC with explosion-proof options

The HI-TBS programmable logic controller (PLC; photo) combines ultra-bright LED technology with 0.1% accuracy to deliver a customizable digital panel meter for applicational use across a wide variety of industries. In addition to serving as a PLC, the TBS is also serviceable as a remote display/controller in applications requiring a computing controller, a DCS for process interface, SCADA interface and single-loop processes. Comparable to the industry-standard 4-in. ANSI meter, the TBS is also available in an explosion-proof housing and sanitary case for Class1E applications. — *Otek Corp., Tuscon, Ariz.*
www.otekcorp.com

Quantitative/qualitative analysis of gases at ambient pressure

OmniStar (photo) and ThermoStar GSD 350 are compact, portable benchtop instruments for analyzing gases at atmospheric pressure. They are particularly used for applications in chemical processes, in the semiconductor industry, metallurgy, fermentation, catalysis, freeze-drying and environmental analysis. The gas inlet is fitted with a heated capillary for use at up to 350°C. This prevents vapors from condensing during process gas analysis. Thanks to the two-stage inlet system, an almost segregation-free gas supply is possible. The ThermoStar was specially developed for coupling with thermo balances. The inlet system with a quartz capillary and a platinum orifice ensures that even the smallest concentrations can be analyzed. The OmniStar was developed for a wide range of applications and uses a stainless-steel capillary as well as a valve which can interrupt the sample gas stream. Unlike other analytical methods such as FTIR or GC-FID, the two new devices allow simultaneous detection of all gases within the mass range. — *Pfeiffer Vacuum GmbH, Asslar, Germany*
www.pfeiffer-vacuum.com

New technologies enhance metallic filter elements

This company has launched a range of surface-modification technologies that can be applied to metallic filter elements (photo) to enhance their material properties in challenging environments, improving filter performance and lifetime. Sinterguard PHC extends the life of 316 stainless steel and exotic alloys in highly corrosive fluid environments. Sinterguard HTR extends the service life of 316L stainless steel and exotic alloys at elevated temperatures. In addition to corrosion resistance, these technologies can enable increased temperature resistance, enhanced chemical compatibility or inertness, improved cleanability (both in situ within the process or offline) and enhanced wear resistance. — *Porvair Filtration Group, Ltd., Fareham, U.K.*
www.porvairfiltration.com ■
Mary Page Bailey and Gerald Ondrey

Part 1

Building a Sustainable Coatings Infrastructure

Recent advancements in coatings technologies are driving the industry toward more sustainable performance

Madison Sloan, L. Elise Matolyak and Rebecca Chen
PPG

IN BRIEF

CHEMISTRY AND FORMULATION

SUSTAINABLE SYSTEM INTEGRATION

LIFECYCLE ASSESSMENT

Globally, there has been an increase in the number of chemicals identified as "chemicals of concern," as well as restrictions on the emissions of volatile organic compounds (VOCs), resulting in new federal initiatives and driving the development of new manufacturing processes. One of the more significant global initiatives for chemical restriction is China's 13th Five-Year Plan (2016–2020), which has identified environmental protection as a key objective [*1*]. China's Five-Year Plan is driving more government regulations involving sustainability and corporate social responsibility, especially in manufacturing processes [*1*]. These regulations have a major impact, specifically for paints and coatings, since solvent-borne technologies will be restricted in China by the end of 2020 [*1*]. Thus, technological advancements in industrial coatings are essential in this environmentally conscious world to support coatings end-users as they make transitions in technology (Figure 1).

The complexity of changing the industrial culture mandates that manufacturers consider how best to implement sustainable coatings systems. As manufacturers are increasingly cognizant of the globalization of products, they are keenly aware of environmental requirements that must be considered. This article covers some industrial developments related to sustainable coatings, as well as methods to facilitate their implementation as an industry standard.

Chemistry and formulation

With increasing regulations and heightened awareness about the environmental impact

TABLE 1. COATINGS TECHNOLOGIES TO REDUCE OR ELIMINATE VOCS

Technology	Advantages	Limitations
Powder [*2*]	· Can apply a thick coat in one application (≥ 50 µm) · Requires no mixing or stirring · Has efficient material use (potential of 100% transfer efficiency)	· Requires special handling of heated parts · Uses electrostatic application systems, making complex shapes difficult to coat · Difficult to incorporate metal flake pigments · Is not applied to plastic substrates
High-solids [*3, 4, 5*]	· Can apply thick or thin coat · Has less overspray compared to conventional coatings	· Does not eliminate solvent completely · Has shorter pot life than conventional coatings · Usually requires heating
Waterborne [*6,7*]	· Can apply thick or thin coat · Uses water for cleanup · Is compatible with conventional and electrostatic application equipment	· Flow properties and drying rates can fluctuate with humidity and temperature · High surface tension can lead to poor flow and dewetting · Requires equipment compatible with waterborne systems · Requires atmospheric-controlled storage conditions · Tends to be low solid content
Radiation-cure [*8,9*]	· Can apply thin coat (< 50 µm) · Has efficient material use (nearly 100% transfer efficiency)	· Is typically best applied to flat materials · Is limited to thin coatings · Requires specific ultraviolet equipment · Can result in yellow color

FIGURE 1. Industrial coatings are essential to preserve the lifetime of equipment and infrastructure, and much research and development work is being done to improve their sustainability footprint

of VOCs, there are a number of innovations within the coatings industry that are focused on improved sustainability. For instance, powder coatings eliminate the use of solvents and have excellent transfer efficiency [*2*]; however, complex shapes and edge coverage can be challenging for powder-based systems. Therefore, the research and development of high-edge powder solutions is imperative to help improve the corrosion resistance of this technology [*2*]. While some coatings technologies, such as powder, high-solids, waterborne and radiation-cure, help reduce the carbon footprint of coatings, each has its limitations. Table 1 gives a brief summary of the coating technologies that can reduce or eliminate VOCs. In this description, a thick coating has a dry-film thickness (DFT) of greater than 50 µm, and a thin coating has a DFT of less than 50 µm. DFT ranges are based on a plethora of factors, including solids content, pigmentation and application parameters.

One major area of research in the development of sustainable coatings products is waterborne technologies, which span numerous markets and have heightened popularity as a decorative coating opportunity (Figure 2). Waterborne coatings are a versatile option, compatible with many

FIGURE 2. One major area of development in sustainable coatings is waterborne formulations, which present many benefits

application methods and can be applied at a range of thicknesses and utilized on multiple substrates. The main difference between solvent-borne coatings and their waterborne analogs is the binder system. Solvent allows for resins to be solvated in the coating system and aids in additive and pigment dispersion, as well as coalescence. Waterborne systems mainly consist of dispersions of polymer particles and require a stable colloidal system. While waterborne coatings present a good opportunity as a low-VOC option, many still contain some level of solvent to help with surface tension and pigment dispersion, requiring further research to reduce solvents and regulated materials while balancing additional performance properties. For instance, some basecoats on plastic substrates can suffer from adhesion loss due to the high surface energy of water, reduced wet-out and a lack of solvent to etch the substrate. Several approaches can be used to address adhesion issues, such as resin innovation and formulation tools. Internal resin capability addresses these obstacles by utilizing chemistries to promote adhesion to diverse substrates, choosing surfactants to aid in reduction of surface tension, and fine-tuned crosslinking in both one-component and two-component coating systems. Additional formulation tools to replace solvents, such as flow additives, coalescents and wetting agents, assist in balancing the necessary properties of a waterborne system.

In addition to adhesion, appearance may be a concern with waterborne coatings. Solvent-borne basecoats achieve metallic flake orientation and a high metallic appearance due to the high volatility of solvents and the ability of solvents to disperse flake pigments. Waterborne basecoats can achieve high metallic finishes through careful choice of flake and passivation, rheology control and resin innovation. Even when flake orientation is achieved, it has been historically difficult to balance high metallic finishes and required performance attributes, such as hardness, with waterborne systems. In aqueous metallic basecoats, multiple resins are often utilized to balance both appearance and performance, and additional formulation tools to enhance rheological requirements for flake orientation and stability are utilized. Rheological effects are constantly being researched to overcome a wide range of obstacles, such as pigment dispersion, paint stability and pumpability, as well as application of emulsion-based systems.

Sustainable system integration

While many companies have been deeply involved in sustainable coatings innovations, the success of the industry's transition, however, heavily depends on the effectiveness of total solutions training. Waterborne and high-solids, solvent-borne paint and coatings commonly have different physical properties than their traditional solvent-borne counterparts, which require additional considerations and equipment during processing. In order to reduce the impact on users adopting these technologies, a multi-step process should be developed for seamless conversion. This process includes assessing the raw material and application requirements for the specific paints or coatings being used, the type of equipment required for processing and full system training for the workers responsible for maintaining and ap-

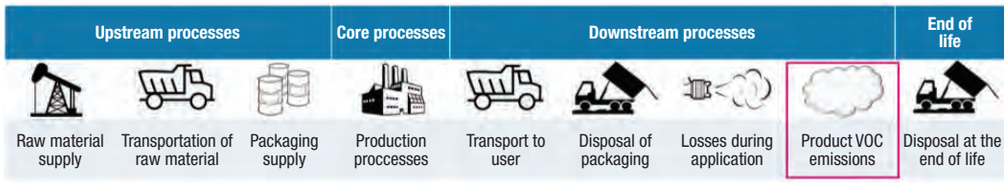


FIGURE 3. A standard lifecycle assessment will highlight the stages that contribute waste of energy, materials or potential sources of environmental impact

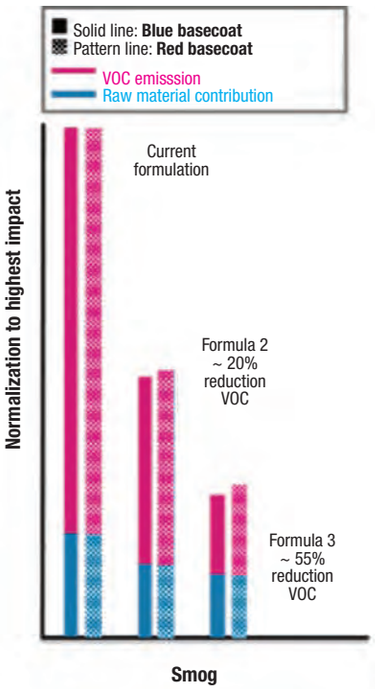


FIGURE 4. This lifecycle assessment compares three waterborne basecoats, looking at the environmental impact of varying levels of VOC content

plying the paint or coating.

For example, the raw materials that comprise a waterborne paint are very different from their traditional solvent-borne counterparts. This is largely due to the modification requirements and balancing material properties to meet specifications. With the increase in the preference for sustainable products, more waterborne raw-materials suppliers have emerged globally. However, until their supply level matches or exceeds those for traditional solvent-borne systems, suppliers will be forced to work with limited supply and extended lead times. Current suppliers are contributing to researching and developing raw materials for waterborne products, which leads to the higher price when compared with solvent-borne paint. Additionally, if a raw material is not registered in the country where it will be manufactured or used, the paint supplier must work with the purchaser to ensure that all raw materials are properly identified and registered. These factors considered, technological advancements with waterborne coatings are necessary for purchasers to consider and adopt to remain compliant with industry regulations and stay competitive.

Different chemistries and varying line equipment require training and safety precautions tailored to the specific coating technology and equipment being used. In order to provide training and recommendations for lines, it is essential to have a technical understanding of the equipment, its limitations, and how to handle it. The most effective way to accomplish this is to have a dedicated application facility to replicate the manufacturing lines of coatings end users. For example, to identify the appropriate equipment for each program, a mock trial line is set up. Once the coating-spray process and parameters are identified, a user line survey should be performed to evaluate compatibility and make improvement recommendations. In line with the principle of providing more convenience for users, a team should be established to evaluate paints and coatings in advance to increase recognition and trust from users.

Finally, suppliers must consider the different storage requirements associated with waterborne systems. Since waterborne paints are more susceptible to temperature and humidity fluctuations, they must be stored and shipped in containers that will not exceed the liquid temperature limits for water. While shipping and storing require important considerations, so does the disposal of waste. Temperatures beyond the required limits can cause severe quality issues, which can lead to unsalvageable inventory and capacity waste. This requires the use of insulated or cooled containers. All of these upgrades and development processes contribute to capital investments for both the supplier and the applicators. However, by realizing and addressing these areas early on in the transition, all of the parties in the supply chain can align for seamless conversion into the coating market's sustainable future.

Lifecycle assessment

A very effective way for studying the environmental impact of a coating is to perform a lifecycle assessment (LCA). An LCA analyzes the impact at all stages through a paint's lifetime that impact the environment — from raw material extraction to disposal, as depicted in Figure 3 [*10*]. While it is important to minimize the effects from start to finish, VOC emissions are being targeted the most aggressively in new regulations. In order to better understand how formulation modifications impact the VOC emissions, companies should perform LCAs on their coating materials.

One example of how an LCA is useful in re-formulating paints is shown in Figure 4. This is a comparison of three waterborne basecoats in both red and blue and their influence on greenhouse-gas emissions, ozone depletion and smog production. By doing a side-by-side comparison, we are able to see that by reducing VOCs even by 20%, smog is reduced by almost half of that of the original formulation. Even more, reducing the waterborne basecoat VOCs to 55% shows the greatest impact on environmental pollution.

As global trends and consumer demand encourage companies to develop sustainable solutions, it is the responsibility of industry leaders to not only meet the demand, but to pave the way for the entire industry to follow by providing full-service solutions. The road to sustainability begins by developing a fundamental understanding of what changes are necessary. By beginning with the fundamental chemistry required to provide solutions and tracking the changes through lifecycle assessments, great strides can be made.

Building an effective platform to achieve the adoption of more sustainable coatings requires analysis of the total coatings process — from raw materials and the suppliers, to application methods and the modification of production lines. Looking at the total picture and planning ahead are the keys to preparing users and the industry for the implementation of regulations like the 13th Five-Year Plan. Innovations will continue to improve in order to support the goal of a more sustainable future. ■

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Part 2

Corrosion Protection with Direct-to-Metal Coatings

Understanding the mechanisms driving corrosion-prevention technologies will help engineers to select the best coating materials and application procedures to ensure proper protection

Julie Holmquist, Ana Juraga and Markus Bieber
Cortec Corp.

IN BRIEF

Corrosion is a serious problem for all industries, but especially so in the chemical process industries (CPI). Just a general look at the total cost of corrosion for the U.S. alone is enough to indicate the significance of the issue. The report in Ref. 1 estimated the annual direct cost of corrosion to be $276 billion. Indirect costs, which are more difficult to measure and include losses related to downtime and litigation were estimated to be roughly equal to direct costs, bringing the combined cost of corrosion to $552 billion. The study found the direct cost of corrosion (apart from maintenance and operation) in the chemicals, petrochemicals and pharmaceuticals sectors to be an estimated $1.7 billion [*1*].

Coatings will always be needed on the many metal surfaces in a CPI plant. Because those coatings will be exposed to harsher conditions than average due to the nature of a chemical processing environment, it is important to take corrosion protection into consideration and choose durable coatings. Among the variety of ways to counter corrosion in the CPI, one basic strategy has been, and will remain to be, the use of protective direct-to-metal (DTM) coatings.

How coatings protect against corrosion

Corrosion is a natural reaction between metal and external elements, such as oxygen and moisture. Basic oxidation can occur simply by the exposure of metal to air. However, corrosion reactions accelerate when an electrolyte-containing medium, such as saltwater, is present to facilitate electron transfer between the anode and the cathode of a corrosion cell. Corrosion also intensifies with higher temperatures or the exposure to harsh chemicals, which is why corrosion in a CPI facility can be much more severe than, for instance, a dry warehouse setting.

Coatings have long been a basic means of protecting wood and metal structures from deterioration. While most of us are familiar with house paint used to protect wood from weathering, CPI facilities chiefly consist of metal equipment and structural components in need of protection. Coatings inhibit corrosion by creating a physical barrier between the metal and corrosive elements, and in many cases, incorporate corrosion inhibitors as an extra layer of defense.

Due to the extreme corrosivity of many chemical processes, CPI facilities require more durable coatings than many indoor applications. However, this can also vary from component to component. For example, a stairway railing will not require the same level of durability required in a splash zone, an immersion tank setting or even on a floor exposed to heavy foot traffic. Char-

Cortec

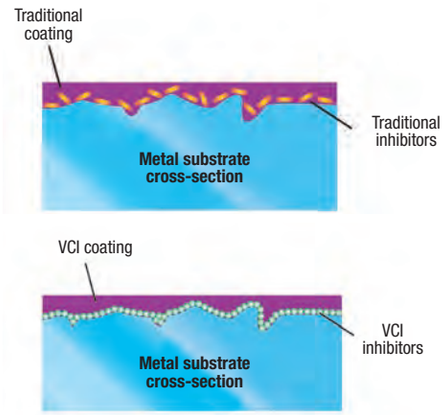

FIGURE 1. The mechanism of vapor corrosion inhibitors (VCIs) involves the formation of a continuous layer of protection that lines the micro-cavities on a metal surface

FIGURE 2. Water-based epoxy coatings of the two-component variety are often used to coat structural steel

acteristics such as these must be taken into consideration when choosing a protective coating.

Micro-corrosion inhibitor options

Sacrificial metals, such as zincs, chromates and aluminum, have been commonly used to create traditional protective coatings. The relatively large particle size of these inhibitors, when considered at the microscopic level, leaves gaps that allow corrosion to get a foothold in micro-cavities and spread more easily from there. An alternative or supplementary technology to standard corrosion inhibitors for coatings are vapor corrosion inhibitors (VCIs), which typically come in the form of salts of amine carboxylates. These corrosion inhibitors have an affinity for metal surfaces, allowing the inhibitors to adsorb and form an invisible, protective molecular layer on the metals. This molecular barrier blocks the electrochemical reaction of metal with oxygen and moisture, inhibiting the flow of electrons in the normal oxidation-reduction reaction that would otherwise cause rust to form.

Because VCIs are relatively smaller and form a much more continuous layer of protection to line the micro-cavities of a metal surface, they are sometimes called "micro-corrosion inhibiting" coatings. Combined with the physical barrier and sometimes also the sacrificial metal inhibitor barrier of traditional coatings, they provide a double or even triple barrier against corrosion, as illustrated in Figure 1 [*2*].

VCIs have an environmental advantage in that they can replace sacrificial metals, and they have been used very effectively to boost the corrosion-inhibiting ability of water-based coatings, which typically benefit from their lower concentration of volatile organic compounds (VOCs) when compared to solvent-based coatings. Data suggest that VCIs also have a synergistic effect with other inhibitors. For instance, when VCIs were added to an acrylic water-based coating containing a non-zinc metal-complex inhibitor, the coating showed improved protection in salt fog testing. The coating blistered less and there was less corrosion on the metal surface than occurred with the coating containing the metal-complex inhibitor only [*3*].

VCIs can be used with many different types of resin systems — both water-based and solvent-based. In the harshness of a chemical process-

FIGURE 3. A large tank for a weir system at a chemical processing plant was coated with a VCI water-based epoxy primer and topcoat for corrosion protection

FIGURE 4. A VCI water-based acrylic topcoat covers this industrial smokestack

ing environment, this will often require users to lean toward solvent-based coatings, but often water-based epoxy and acrylic VCI coatings find their place, as well, improving the overall environmental profile of the application and reducing exposure to VOCs — although solvent-based VCI coatings are typically also compliant with VOC-content regulations.

Choosing a coating

There are many basic areas to coat around a chemical plant — railings, walkways and structural steel — and an additional benefit when using VCI coatings for these areas is that they can be tinted to match the desired color-scheme — whether safety yellow, red, green or blue — to serve the purpose of both corrosion protection and aesthetics. Certainly, the main functionality is to protect the metal from rusting, but a secondary function is to improve appearance.

Depending on the severity of the conditions encountered in a chemical plant, different coatings may be better suited for each application, as the coatings may need to be durable and chemically resistant against varying process media, including fumes and liquids. Often, in these situations, epoxy-based coatings (Figures 2 and 3) are chosen.

Coatings like those illustrated in Figures 2 and 3 can be applied directly to the metal as a one-coat or two-coat system. They can be top-coated with either a VCI water-based acrylic system (Figure 4) or, for higher durability, covered with a one-component VCI solvent-based moisture-cure urethane (Figure 5) or two-component VCI solvent-based urethane coating. For the more extreme conditions, such as those encountered by splash zones, floors or internals of a tank that will be filled with an acid or caustic liquid, it is recommended to simply use a basic 100% solids two-component novolac (special phenol- or formaldehyde-based polymer) epoxy coating that is chemically resistant.

Epoxies and urethanes are among the more durable resin systems and can be fortified with micro-corrosion-inhibiting VCIs. Rust-converting primers for pre-rusted surfaces and novolac epoxies for floors or chemical splash zones are also good options for extreme surface-prep needs and harsh chemical-exposure applications, respectively. For the best performance, application crews should employ best practices to prepare a clean surface and closely follow manufacturer's instructions for coatings application.

Ensuring coating integrity

As important as it is to choose a proper coating, it is also important to take precautions that will help to ensure the best coating integrity. A good coating

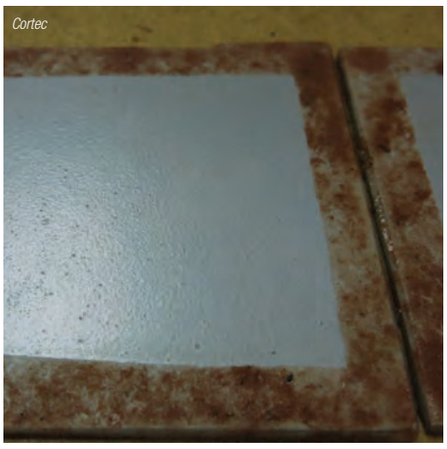

FIGURE 5. Steel panels coated with VCI solvent-based moisture-cure urethane showed corrosion resistance after over 1,000 hours buried in dirt and clay in a humidity test chamber

applied haphazardly to a poorly prepared surface will compromise the durability of the coating much earlier than necessary. Proper surface preparation is vital to creating a coatings system that will last. Other important factors are proper mixing, thickness and weather conditions. Coatings users must ensure that they have the mix ratios correct and that they are applied at the proper thicknesses. Weather conditions also play a role in impacting coating application. For instance, in cold weather, water-based coatings are not going to experience optimal application and curing. Following the manufacturer's recommendations will help to guide users in planning how and when to best apply certain coatings [*5*].

An important and convenient aspect of many VCI coatings is that they can be applied directly to the metal. Some VCI coatings are primers, some are topcoats and some can flexibly serve in either category. Using good primers is an important part of a successful coatings system, because it helps the coatings bond better to the metal surface. While it may not always be practical due to time and budget considerations, the ideal coatings system will include two coats of a primer with a heavy-duty topcoat to finish it. Two-component primers and topcoats are even better, although they require extra mixing to allow the advantages of cross-linking to occur. In these cases, maintenance engineers will need to weigh time, convenience and cost against desired performance.

Dealing with pre-rusted surfaces

Surfaces must be free of rust and contaminants if coatings users want the coating to last as long as possible. For surfaces that have already rusted, this could involve chemical rust removal or some type of blasting. Sandblasting is common, but not always convenient, and sometimes is not even allowed or feasible in certain environments. A convenient alternative is to apply a water-based rust-converting primer that uses polyvinylidene dichloride (PVDC) resins and a chelating agent to turn the rust into a passive layer that seals it off and protects it from further rusting. For situations where either water-based or solvent-based topcoats may be applied, it is ideal to choose a rust-converting primer that is compatible with either coatings system and exhibits adhesion behavior according to ASTM Class 5B. Rust-converting primer is also a good option for structural repairs where concrete has delaminated to reveal rusty rebar. Such a coating can be applied to passivate the rebar before continuing the concrete repair process.

Following this guidance will help maintenance engineers to tackle the challenging corrosion scenarios encountered in CPI facilities and get the best performance possible out of their protective coatings. ■

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Part 1

Pressure Instruments: Avoiding the Harmful Effects of Hydrogen

Under the right conditions, the smallest atom can attack and disable sophisticated instrumentation. Understanding how this happens can help users avoid problems

Keith Riley
Endress+Hauser

IN BRIEF

Engineers of a certain age may remember the childhood disappointment of a helium-filled balloon going flat overnight. This experience illustrates how small atoms, such as helium, can diffuse through materials, even those that seem impermeable, such as the walls of a latex balloon. The lesson learned may come back to mind when trying to diagnose the failure of a pressure instrument installed in an application involving hydrogen.

FIGURE 1. Using a remote diaphragm and fill fluid allows a pressure instrument to be mounted away from a process, avoiding the problems normally associated with conventional impulse lines

Few engineers would consider a vessel constructed of 316 stainless steel or Alloy C to be permeable, but there are situations where austenitic stainless steels and high-nickel alloys can exhibit the same porosity as a balloon due to their grain structure. To be clear, a stainless-steel tank isn't likely to start leaking spontaneously, but permeability can become an issue under specific conditions with specific types of instrumentation. This article discusses how permeability happens in general terms, and then in the context of a specific process application.

Working with the smallest atom

With an atomic number of one, hydrogen is the smallest and lightest atom, composed of one proton and one electron. In its natural state, hydrogen exists as a diatomic molecule, H_2, which is a gas at ambient conditions. The H–H bond is very strong, but under the right circumstances, gaseous H_2 can dissociate, just as a water molecule can dissociate into two ions, OH^- and H^+. An H^+ ion (a cation) is nothing more than a single proton, and it can penetrate through microscopic voids in a thin metal barrier, such as the diaphragm of a pressure instrument (Figure 1). The degree of porosity in the diaphragm metal is influenced by how the metal was formed and welded.

Once the H^+ ions have migrated through the diaphragm, they move into the fill fluid where they capture electrons. These reconstructed atoms now recombine to form H_2 molecules and remain permanently trapped and dissolved in the fill fluid, unable to pass back through the diaphragm as molecular hydrogen. As long as there is sufficient positive pressure on the diaphragm, the hydrogen remains dissolved and there is no problem.

However, if the pressure falls to atmospheric or below, the H_2 can come out of solution and form bubbles in the fill fluid, like CO_2 from carbonated water. This raises the internal pressure behind the diaphragm, which is the weakest point of the containment housing, deforming the diaphragm and causing it to bulge out like a can of spoiled fish, exhibiting the "jiffy-pop" effect (Figure 2).

FIGURE 2. Once hydrogen permeates the diaphragm, it becomes trapped in the fill fluid, gradually building up pressure until it distorts the diaphragm, as shown in these two pictures

The more technical description is catastrophic membrane deformation, which requires replacement of the complete transmitter.

Aqueous applications

A common situation where this happens involves water, a product normally considered benign. The driving force causing ions to migrate from water through a diaphragm is independent of pressure. The action is galvanic, which causes this problem to appear in some unexpected applications, such as wastewater- or biogas-treatment plants.

Picture this situation: a plant's maintenance department installs an access ladder into a large sump pit where a pressure instrument is installed nearby to measure level. The frugal engineer chooses a hot-zinc galvanized ladder rather than stainless steel, hoping to minimize corrosion while saving a few dollars.

After operating for two months, the sump is drained for cleaning and the stainless-steel instrument diaphragm distends due to hydrogen permeation. This negates the cost saving on the ladder, so the maintenance manager wants to know why it happened. After all, it's just water. This isn't a hydrogen application, is it?

It became a problem due to galvanic interaction, or "battery effect," between the components. The zinc on the ladder acts as the anode and the stainless-steel diaphragm of the pressure instrument is the cathode. The water present in the tank is electrolyte.

The result of this galvanic process is a reduction of water molecules into ions at the cathode (Figure 3). Stripped of their electrons and driven by galvanic action, extremely small H^+ cations can diffuse through a 316 stainless-steel or Alloy C diaphragm. As described earlier, once on the other side of the diaphragm, the H^+ ions capture electrons and recombine into H_2 molecules in the fill fluid. This type of diffusion is independent of process pressure, but the diffusion rate can increase with higher temperature.

The solution for this type of situation calls for a two-layer coating to effectively seal the diaphragm (Figure 4).

First a layer of gold (Au), between 15 and 25 µm, is added to the full diaphragm surface. Gold has a very low diffusion coefficient, increasing the hydrogen permeability resistance up to one million times. This is supplemented by an additional coating of rhodium (Rh) on top of the gold. Rhodium promotes recombination of H_2 in the solution, reducing its ability to diffuse. With fewer cations present in the solution, plus a far less permeable diaphragm, the problem can be largely eliminated in most situations.

Gaseous applications

The discussion so far has focused on aqueous solutions with dissociating water molecules, but diaphragm permeation can also take place with gaseous hydrogen where no liquid is involved, although the drivers are different.

Gaseous molecular hydrogen can dissociate into single atoms, and even H^+ ions in situations when the pressure and temperature are high enough (Figure 5). Ions deposit on the pressure instrument diaphragm and can be forced through into the fill fluid, where they pick up electrons and recombine into molecular hydrogen, just like in aqueous applications.

The precise points where temperature and pressure become a factor are difficult to define specifically, how-

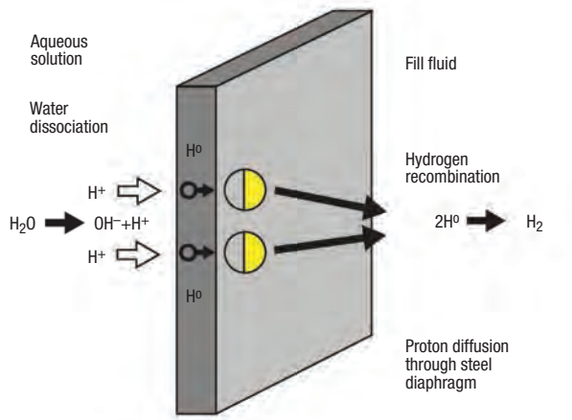

FIGURE 3. In aqueous solutions, galvanic action can cause water molecules to dissociate and diffuse through the diaphragm

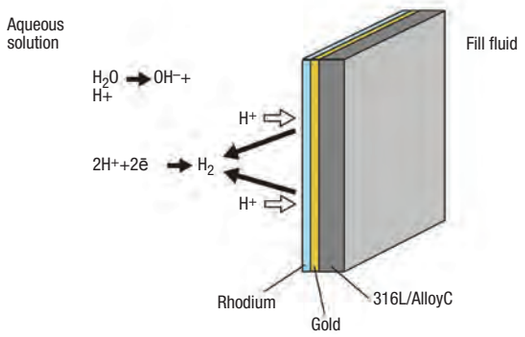

FIGURE 4. Adding a double coating of gold and rhodium reduces permeability and promotes reformation of molecular hydrogen

ever, when both variables increase together, the effect is compounded, increasing the rate of permeation.

The solution is different, however, than aqueous applications and calls for a single coating of gold on the diaphragm, without the rhodium overcoat (Figure 6).

The rhodium only performs its function in an aqueous environment, so it serves no purpose here. A gold coating of 15 to 25 µm increases permeability resistance by up to one million times, reducing the potential for instrument failure. Increasing coating thickness increases resistance, so a heavier coat extends the operating temperature range. For example, a 15-µm coating is rated for 180°C (356°F), while a 40-µm coating is good to 250°C (482°F).

How much protection is enough?

Adding a layer of gold to a stainless-steel or high-nickel-alloy diaphragm does indeed reduce permeability by a very high degree, but it does not eliminate it entirely. A pressure instrument diaphragm must be thin to be effective, so there is always some vulnerability. The problem is made worse by the fill fluid because the medium is able to capture hydrogen ions and allow them to re-associate in the confined space. The better solution is to use a different pressure-measuring approach that is able to eliminate both problem areas.

Better diaphragm material. The first step is to eliminate the metallic diaphragm, replacing it with a material capable of zero or at least much lower permeability, and not able to participate in galvanic reactions. This suggests something non-metallic, but the material must also be capable of handling high pressures and temperatures. One answer is a ceramic diaphragm, which is impervious to direct hydrogen diffusion and is non-conductive. This way, no metallic component needs to be exposed directly to the process liquid or gas.

No fill fluid. Using a ceramic diaphragm eliminates the need for fill fluid, so there is no medium capable of capturing and accumulating H^+ ions. How does this approach work?

Ceramic diaphragm. The ceramic diaphragm exposed to the process is the measurement point. This is possible using capacitance technology in a "dry cell" configuration (Figure 7). The back side of the diaphragm has a metal coating, capable of moving with the diaphragm as it flexes in response to pressure. The coating forms one electrode of the sensor, and a spacer around the perimeter holds it away from the cell's back side and maintains a desired separation.

The back side has two electrodes, one in the center and one around the outside. The outer electrode serves as a reference and the center provides a variable signal used to measure pressure. This assembly is sealed to maintain process containment. When used in a gage pres-

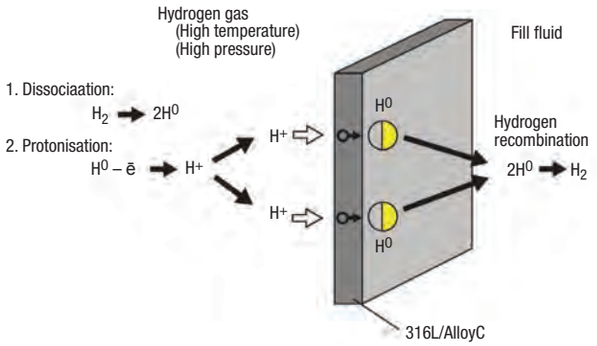

FIGURE 5. Molecular hydrogen can disassociate and form H^+ ions , which are capable of permeating a diaphragm

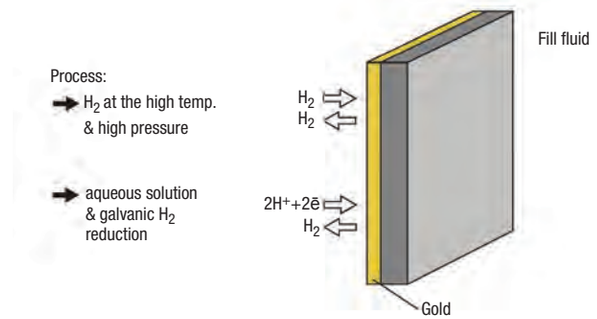

FIGURE 6. A coating of gold on the diaphragm reduces permeability for both gaseous and aqueous applications. Increasing the coating thickness increases the effective temperature range

sure measurement setup, the interior space is vented to atmosphere through the instrument housing.

As the diaphragm flexes due to pressure, the distance between the electrodes changes and the capacitance value changes with it. This provides the raw analog signal processed by the instrument's transmitter. This configuration is especially well-suited to hydrogen service because neither molecular hydrogen nor H^+ ions can diffuse directly through the ceramic material. Even if hydrogen manages to penetrate the assembly seal at the edge, it will have no effect. There is no fill fluid and the interior space is vented, so such trace amounts simply escape through the instrument.

A ceramic diaphragm is significantly more durable than stainless steel or high-nickel alloys, even when they are coated with gold. It also provides wide temperature and pressure capabilities, assuring a long service life with full integrity.

Example: Ultra-pure polysilicon

Hydrogen gas is used in many processes, both as a component to facilitate a specific reaction or as the end product — for example, as a component in ammonia used for fertilizer production, a fuel source, or a reformer byproduct in hydrotreating and hydrocracking processes. One lesser known, but highly important, use of hydrogen is in the production of ultra-pure polysilicon.

The polysilicon wafers used to form the base for computer chips, photovoltaic cells and various other electronic devices have to be manufactured with a degree of purity that is unimaginable in most industries. Polysilicon for photovoltaic cells must approach 99.999999% purity, achieved through a complex and very hot process. Polysilicon for computer chips must be even purer.

The process begins by turning sand and coal into metallurgical silicon (99% pure) in an arc furnace. Crushed metallurgical silicon is then fed into a fluidized-bed reactor to mix with hydrogen chloride gas at 300°C (572°F). This creates a mix of compounds, including trichlorosilane ($HSiCl_3$) as the primary product. The mixture can be separated using multiple distillation steps, isolating trichlorosilane from the byproducts and purifying it.

All the byproducts and contaminants must be removed for the next step of the process to work correctly and deliver the necessary final product. The purified trichlorosilane is mixed with purified hydrogen and fed into a highly specialized reactor.

Inside the reactor, thin filaments of polysilicon, fabricated into squared inverted U shapes, are mounted on the floor (Figure 8). A typical reactor supports 15 to 20 of these, often up to four meters tall, within the vessel. The filaments are heated electrically to 1,150°C (2,102°F) while trichlorosilane gas is pumped in along with molecular hydrogen to a pressure of 5 bars. As the reactor interior heats up, the trichlorosilane decomposes and deposits pure polysilicon onto the glowing filaments. Other byproducts from the reaction are extracted and captured for recycling.

This process continues for several days, with a constant flow of the feed gases, eventually building up the filaments from a few millimeters to 200 mm in diameter. Feed gas flow and pressure must be controlled carefully to ensure the fastest material deposition without wasting unreacted gas.

This is a challenging process, to say the least. The chemicals involved are highly flammable, corrosive, toxic and react violently with water. The process is energy intensive and costly, so ensuring careful control and stability are paramount. Temperature fluctuations can cause cracking or splintering, and even the slightest contamination renders the product unusable.

For a pressure instrument, this application is as challenging as they come. Pure hydrogen at a high temperature and pressure provides all the conditions necessary to drive hydrogen permeation through a conventional stainless steel or high-nickel alloy diaphragm. This

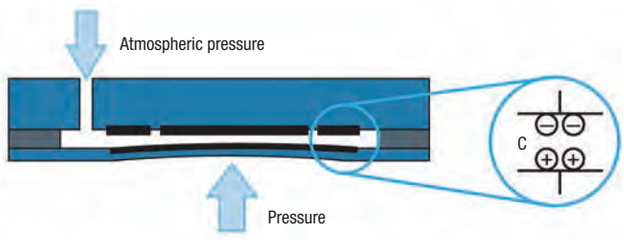

FIGURE 7. Using a ceramic diaphragm in a dry cell assembly does not allow any internal pressure to accumulate, thereby protecting the instrument

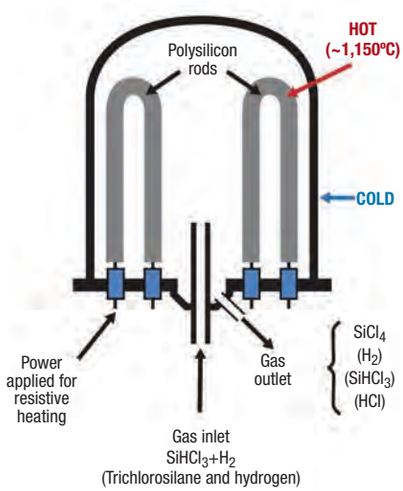

FIGURE 8. Through a long process of gaseous deposition, ultra-pure polysilicon builds up on the filaments

is made worse by regular cycling of the reactor, allowing pressure to drop to atmospheric when each charge is completed. Any hydrogen that migrates through the diaphragm and into the fill fluid can potentially bubble out and deform the diaphragm.

Given the extreme process temperature, an instrument to monitor gas pressure is usually located on the feed pipe, where the temperature is much lower. Nonetheless, with 5 bars pressure, conditions are optimal for creating hydrogen permeation able to cause instrument failure. This calls for gold coating on the diaphragm to minimize permeability.

Multiple solution possibilities

Hydrogen service, as discussed here, presents critical challenges fully capable of causing instrument failure. However, there are solutions that can reduce the problem, and often eliminate it entirely for all practical purposes. For users, the lesson should be that no challenge must be tolerated over the long term. Instrumentation companies are generally very responsive to the needs of manufacturers and have found many creative approaches to solve or at least manage problems that may have seemed unsolvable. The answer is engaging the vendor as a trusted partner, one with extensive domain expertise and a full portfolio of solutions. ■

Acknowledgment

All images courtesy of Endress+Hauser.

Author

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Part 2

Mechanical Pressure Gages in the CPI

In today's digital age, there is still a need for mechanical pressure measuring instruments for safety, efficiency and economical advantages. Selecting the right type is described here

Silvia Weber
WIKA Alexander Wiegand SE & Co. KG

IN BRIEF

Whether at work or at home, more and more areas of life are, or will become, digital. Nevertheless, the manufacturers of mechanical pressure-measuring instruments continue to see rising sales of their gages. Customers in the chemical process industries (CPI) immediately mention two reasons for this continuing strong demand: the safety and efficiency of these instruments.

Pressure gages always provide a reliable measurement result that can be read at a glance, with no external power. Even if the power supply fails, they continue to fulfil their measuring task and display the value locally. The continued and widespread use of mechanical pressure-measuring instruments also has an economic basis. Mechatronic and electronic solutions require a higher investment. However, not all employees work in the control room or have a laptop in front of them in order to monitor the measurement processes. In most cases, the service and maintenance personnel are found within the plant and can thus read the pressure directly on site.

Types of gages

The basic decision to use pressure gages is easily understandable. In contrast, the answer to the question of which instrument suits which requirement is more complex.

Technologically, we distinguish three types of pressure gage (Figure 1): Bourdon-tube pressure gages work with a Bourdon tube as a measuring element, which expands with increasing pressure. This travel is transferred to the display through a link and a movement. With diaphragm pressure gages, the pressure acts on a diaphragm, which is either clamped or welded around its edge. The linear motion is transmitted via a link directly to a movement. Due to the large surface area of the diaphragm element, low pressure ranges can be measured ($p = F/A$). A special form of this type of gage is the capsule pressure gage. The measuring element is made of two diaphragm elements, welded together around their edges. The resulting double tube travel enables the measurement of even the lowest of pressures without reducing the material thickness.

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Selection criteria

All three technologies are equally suitable for monitoring gage, differential and absolute pressure. In general, gage pressure measurement is the most commonly used method. With this, the difference is measured to the currently prevailing ambient pressure, which is determined by the weather and the altitude above sea level. Compared to the other two methods, gage pressure measurement involves less effort and still meets most of the requirements within the CPI.

The EN 837 "pressure-gage standard" therefore covers mechanical measuring instruments with an elastic element for gage pressure up to a maximum of 1,600 bars. It is divided into three parts: "Bourdon tube pressure gages — Dimensions, metrology, requirements and testing" (EN 837 Part 1), "Selection and installation recommendations for pressure gages" (EN 837 Part 2) and "Diaphragm and capsule pressure

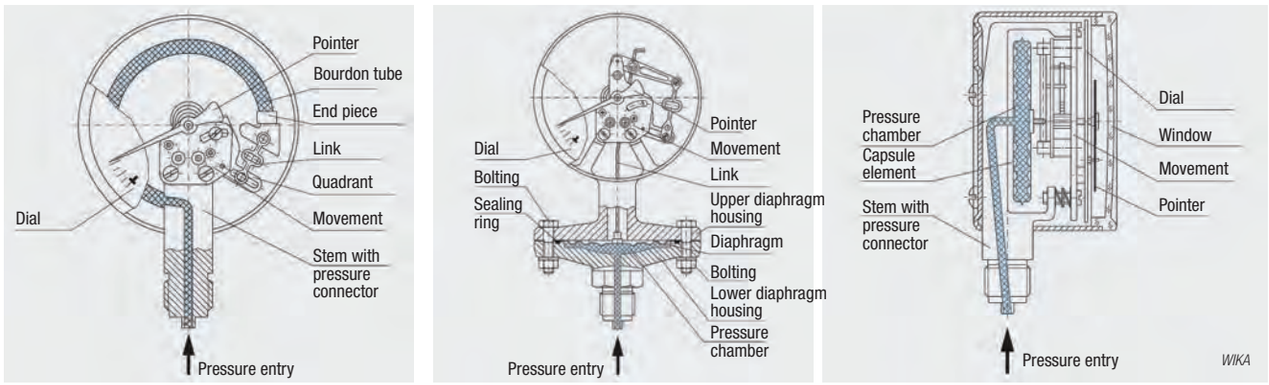

FIGURE 1. Pressure gages can be categorized into three types: Bourdon tube (left), diaphragm element (middle) and capsule element (right)

gages — Dimensions, metrology, requirements and testing" (EN 837 Part 3). DIN, the German Institute for Standardization, has meanwhile published binding standards for pressure gages not covered by the European standard: DIN 16001 for high-pressure gages, DIN 16002 for absolute-pressure gages and DIN 16003 for differential-pressure gages. However, since EN 837 is applicable to more than 80% of all pressure gages, the information in the following selection criteria is based on this standard.

The first consideration after the type of pressure is the pressure range, whose limit values are defined in EN 837 according to the technology (Table 1). The range from 1 mbar to 600 mbar is covered with capsule element instruments. Models with multiple, cascaded capsule elements can detect even the smallest pressures. To display values between 2.5 mbar and 25 bar, diaphragm pressure gages are recommended. For ranges between 0.6 bar and 1,600 bars, Bourdon-tube pressure gages are predominantly suitable. Higher pressures, such as in the production of low-density polyethylenes, occur only occasionally in the process industries. Nevertheless, there are Bourdon-tube designs for pressures up to 7,000 bars, which have been developed on the basis of finite-element analysis (FEM) and using specific materials and geometries.

Alongside the pressure range, the measured medium plays a crucial role. If one takes this criterion as a benchmark, the diaphragm pressure gage presents itself as an all-arounder. Models with Bourdon tubes, however, should not be integrated into processes with highly viscous or crystallizing liquids, since the pressure connection and Bourdon tube have a small cross-section and thus can "clog." The very sensitive capsule pressure gages are only suitable for use with gases or vapors: a liquid medium in the capsule would distort the measurement result due to its own weight.

Particularly the materials of the instrument components that come into contact with the medium also have to be suitable for this medium. For non-problematic substances, a copper alloy will suffice, while for aggressive or corrosive media, process connections and measuring elements from high-grade 316 stainless steel should be used. Depending on the requirement, special materials such as Hastelloy, Monel and tantalum can also be utilized. This is especially true for diaphragm elements, which can also be coated with polytetrafluoroethylene (PTFE), gold or platinum, for example.

Besides critical media, pressure gages in the CPI are also exposed to a high number of load cycles. The requirements for reliability and durability are correspondingly high. In addition to the quality of design and functionality, the display accuracy is another of the selection criteria. The EN 837 standard defines seven classes of accuracy from 0.1 to 4.0%, indicating the error limits as a percentage of the measuring span (Table 2). In the CPI, classes 1.0 and 1.6% are the most widely used.

The nominal size (NS) of a measuring instrument gives information about its readability. At the same time it relates to the display accuracy. The rule of thumb is that the better the accuracy class, the greater must be the diameter of the dial in order to resolve the pointer deflection precisely. An accuracy class of 1.0% requires an NS of at least 63 mm.

Working with critical media or in harsh environments can make it necessary to have a special design of pressure gage. Measuring instruments in a safety version (marked with an "S" in a circle on the dial in accordance with the standard) have a solid baffle wall between the measuring element and window as well

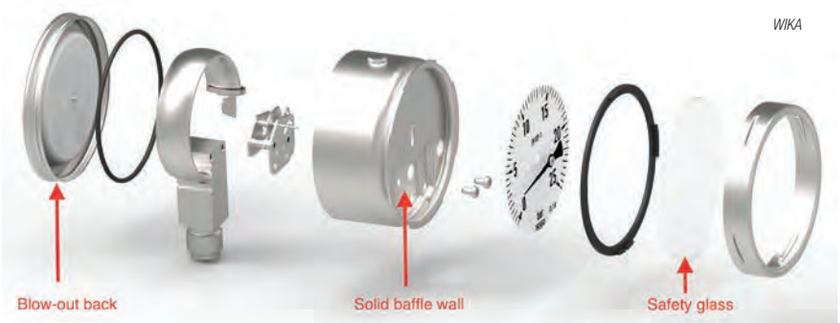

FIGURE 2. For protection against explosions, special gages have a blow-out back and a solid baffle wall

TABLE 1. THE EN STANDARD FOR THE THREE TYPES OF PRESSURE GAGE

Reference of the Standard	Type of pressure gage	Pressure range	Process fluid			
			Gas or Steam	Liquid		
				Low viscosity	High viscosity	Polluted
EN 837-1	Bourdon tube	0.6–1,600 bars	X	X	1)	1)
EN 837-3	Diaphragm	2.5–25 bars	X	X	X	X
EN 827-3	Capsule	1–600 mbar	X	X2)		

Note 1) Separators should be used
Note 2) The capsule and the pipe shall be fully filled with the liquid

as a blow-out back. In the event of damage (Bourdon tube bursting), the baffle wall ensures that any energy arising is dissipated through the back of the unit. The front window, in most cases made from safety glass anyway, remains intact, and any personnel who happen to be checking the pressure at that instant are protected.

Safety in critical situations

Where strong vibrations could damage or destroy a measuring instrument, a pressure gage with liquid filling is recommended. The liquid (usually glycerine) absorbs the vibration acting on the instrument and thus also the oscillations of the pointer, so that the measured value can still be read correctly. Moreover, the liquid acts as a lubricant between the mechanical components, which increases the durability of the pressure gage.

For other typical applications, measuring instruments can be exposed briefly to elevated pressures, such as when switching on a pump or opening/closing a valve. For this, diaphragm pressure gages are better suited than Bourdon-tube pressure gages due to the diaphragm being attached to the upper flange. Some diaphragm pressure gages, for example, come as standard with an overpressure safety of five times the full scale value. For the lowest measuring ranges (from 16 mbar) there are special versions that can withstand an overpressure of up to 400 bars. Bourdon-tube pressure gages can only be protected through a high design input to prevent plastic deformation of the measuring element. This is achieved by means of an additional link and an overpressure bracket. For pressures above the nominal value both components interlock, tube resistance increases and the motion of the measuring element is limited.

Final remarks

Due to their advantages, mechanical pressure-measuring instruments will continue to be indispensable for instrumentation in the process industries. Their only limitation: they cannot perform any control or regulation tasks. Their electronic "cousins" are necessary for this. Anyone who, for safety reasons, still needs an additional local display, free from external power, does not automatically have to operate with two measuring points. The dual function needed may be fulfilled by a mechatronic instrument; that is, a combination of pressure gage and electrical output signal or switch contact. Such two-in-one solutions save space and expense — which really assists in the cost-effectiveness of the process. ■

Edited by Gerald Ondrey

TABLE 2. ASSIGNMENT OF ACCURACY CLASSES TO NOMINAL SIZES

Nominal size	Accuracy class						
NS	0.1	0.25	0.6	1	1.6	2.5	4
40 and 50					X	X	X
63				X	X	X	X
80				X	X	X	X
100				X	X	X	
160		X	X	X	X		
250	X	X	X	X	X		

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Economic Indicators

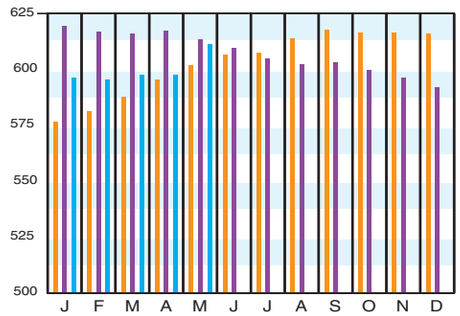
2018 2019 2020

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	May '20 Prelim.	Apr. '20 Final	May '19 Final
CE Index	593.6	595.6	613.5
Equipment	720.3	723.4	748.7
Heat exchangers & tanks	616.1	620.6	665.8
Process machinery	721.1	725.4	730.7
Pipe, valves & fittings	942.2	944.3	965.4
Process instruments	409.6	411.3	419.0
Pumps & compressors	1086.3	1086.3	1068.9
Electrical equipment	561.1	561.3	557.6
Structural supports & misc.	774.0	777.8	818.0
Construction labor	334.1	332.6	335.6
Buildings	587.5	591.0	597.8
Engineering & supervision	312.6	313.0	316.4

Annual Index:
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5

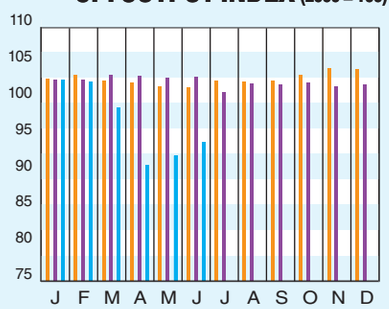


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

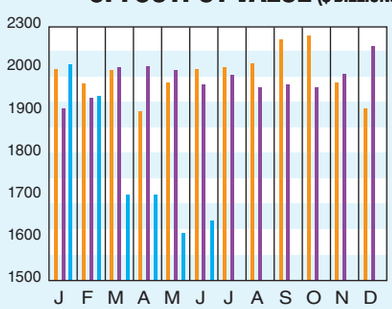
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS	YEAR AGO
CPI output index (2012 = 100)	Jun. '20 = 92.5	May '20 = 89.3	Apr. '20 = 88.6	Jun. '19 = 101.6
CPI value of output, $ billions	May '20 = 1,637.9	Apr. '20 = 1,587.3	Mar. '20 = 1,809.5	May '19 = 2,035.9
CPI operating rate, %	Jun. '20 = 68.9	May '20 = 66.5	Apr. '20 = 66.2	Jun. '19 = 75.8
Producer prices, industrial chemicals (1982 = 100)	Jun. '20 = 211.9	May '20 = 203.1	Apr. '20 = 211.9	Jun. '19 = 253.8
Industrial Production in Manufacturing (2012 =100)*	Jun. '20 = 93.3	May '20 = 87.0	Apr. '20 = 83.8	Jun. '19 = 105.0
Hourly earnings index, chemical & allied products (1992 = 100)	Jun. '20 = 186.6	May '20 = 188.7	Apr. '20 = 193.6	Jun. '19 = 185.3
Productivity index, chemicals & allied products (1992 = 100)	Jun. '20 = 98.7	May '20 = 99.3	Apr. '20 = 99.4	Jun. '19 = 96.3

CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)

*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for May 2020 (the most recent available) decreased compared to the previous month's value, following a similar decline in April. The values for three of the four major subindices (Equipment; Buildings; and Engineering & Supervision) comprising the CEPCI saw a decrease, while the Construction Labor subindex showed an increase. The current CEPCI value is 3.2% lower than the corresponding value from a year ago. Meanwhile, the Current Business Indicators (CBI; middle) showed increases in the June CPI Output Index and the June CPI Operating Rate, as well as the May CPI Value of Output. Producer prices for industrial chemicals were also up in June.